

AD-A257 668



**A RAND NOTE**

**Adaptation to Change in the U.S. Machine Tool  
Industry and the Effects of Government Policy**

**Arthur J. Alexander**

**September 1990**

92-30540

DTIC  
ELECTE  
DEC 01 1992  
S E D

**DISTRIBUTION STATEMENT**

**Approved for public release  
Distribution Unlimited**

**RAND**

The research described in this report was supported by the U.S.-Japan Foundation of New York and by The RAND Corporation using its own research funds.

**The RAND Publication Series:** The Report is the principal publication documenting and transmitting RAND's major research findings and final research results. The RAND Note reports other outputs of sponsored research for general distribution. Publications of The RAND Corporation do not necessarily reflect the opinions or policies of the sponsors of RAND research.

## **A RAND NOTE**

**N-3079-USJF/RC**

**Adaptation to Change in the U.S. Machine Tool  
Industry and the Effects of Government Policy**

**Arthur J. Alexander**

**September 1990**

**Supported by the  
U.S.-Japan Foundation of New York**

**RAND**

## PREFACE

This Note represents research into the adjustment process of the machine tool industry in the United States as it faced the challenges of a secular decline in domestic demand compounded by the effects of economic recession and acceleration of foreign competition. The Note sought to produce a picture of the industry's response and adaptation to events, the path of output and the movement of capital and labor, and the influence of government policies on these adaptations. Of interest were not only government policies directly related to trade effects and to declining industries, but also more general policies that may have influenced the ability of U.S. machine tool firms to react to a variety of forces, the likes of which the industry had not witnessed in its long history.

This Note was supported by a grant from the U.S.-Japan Foundation of New York and by The RAND Corporation using its own research funds. It was prepared as part of a larger RAND project, "Adjustment Mechanisms and Public Policies Towards Troubled Industries in the United States and Japan." An earlier draft of this Note was presented at the U.S.-Japan Conference on Troubled Industries, held in Tokyo in February 1989, and hosted by the Japan Center for Economic Research, RAND's Japanese collaborator on the project.

Accession For	
NTIS CRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification _____	
By _____	
Distribution /	
Availability Codes	
Dist	Avail and/or Special
A-1	

DTIC QUALITY INSPECTED 2

## **SUMMARY**

### **MACHINE TOOL TRENDS**

Machine tool production in the United States has always been highly volatile; it suffers from a double dose of the accelerator principle affecting investment goods, since machine tools themselves are a major input in the production of other investment goods. Although the average before-tax return of machine tool companies has been about equal to the return for all manufacturing, the standard deviation of annual returns is more than four times greater.

The wide cyclical movements have obscured long-term trends in domestic machine tool demand, which is experiencing secular decline; machine tools have fallen from 15–20 percent of the value of total equipment investment in the 1960s to 10–15 percent in the 1980s. This decline has resulted from several sources: substitution of nonmetallic materials for metals, the development of alternative metal-cutting technologies, the declining output of products that had been heavy users of machined parts, and increased productivity of machine tools themselves, which reduces their required numbers.

In addition to the long-run fall in domestic demand, imports have increasingly dominated the U.S. market, the import share of consumption having risen from around 10 percent in the late 1960s to 50 percent in the 1980s. Since the mid-1970s, Japan has become the largest source of foreign machine tools in the United States, aided by a general overvaluation of the dollar in the 1980s, the introduction of new Japanese models, and the ability of Japanese companies to produce and stock products during slack periods that were then available for immediate delivery during upturns.

Employment reached a high in 1952 of 125,000, falling to 50,000 in the late 1980s. Labor productivity has fallen since 1969, and in 1986 was below its 1958 value.

### **INDUSTRY STRUCTURE**

The absolute size of the entire U.S. machine tool industry is small. It is characterized by small size firms and establishments. Ninety percent of the firms had fewer than 100 employees; only seven had more than 1000 employees.

Economies of scale in manufacturing seem to be exhausted at establishment sizes of a few hundred employees. Because of the absence of scale economies in production, mergers and acquisitions have been few and random, although some conglomerates have attempted consolidation of excess capacity and centralization of finance and R&D. Several such consolidations in the early 1980s were later dissolved, but some new attempts thus far seem to be more successful.

As predicted by theory, large firms were more severely affected by declining demand than small firms. The 1000-plus establishments fell from 25 in 1967 to seven in 1986; the number of establishments fell for all size categories larger than 250 employees, while the number of the smaller establishments of fewer than 50 has risen.

An important trend affecting the machine tool industry worldwide has been the disintegration of production, with competition for components and specialized parts growing on a global basis. This pattern of out-sourcing is leading to the producers of complete machine tools becoming R&D and assembly concerns rather than manufacturing firms. One measure of vertical disintegration is the ratio of value added to sales, which has fallen from a figure of about 0.66 at the cyclical peaks through the 1970s, to an all-time low value of 0.52 in 1986.

Technological change in the 1970s and 1980s favored flexibility in design, development, and production; together with intensified worldwide competition, these changes led to shorter product cycles, quicker product development, and a push for speedier order delivery. The technological and market changes created an advantage for numerical control machines assembled from standardized modules that challenged the traditional machine tool choices at both the low and high volume production sectors. To take advantage of the technological and market opportunities, firms had to totally reorganize their management of R&D production, and processing of orders. Japanese machine tool companies adapted to these changing conditions a decade or more before the U.S. industry. Thus, the U.S. firms were also caught short in product technology and management innovation.

## **GOVERNMENT POLICIES TOWARD THE MACHINE TOOL INDUSTRY**

In 1986, the Department of Commerce accepted a machine tool industry petition for relief from imports as a threat to national security (based on Section 232 of the trade law) for seven of the 17 types of machine tools mentioned. Rather than issuing unilateral

presidential directives to control imports, the government sought restraints through the mechanism of Voluntary Restraint Agreements (VRAs). Japan and Taiwan formally signed VRAs, but Germany and Switzerland refused. The agreements limited imports of numerically controlled machines to their 1981 U.S. market share and other machines to their 1985 share, becoming effective at the beginning of 1987. The import quantity of restricted items fell by almost 28 percent in 1987, compared with a 13 percent fall in unrestricted items; but the prices of the restricted items rose an average 16.6 percent, versus a 6 percent increase for other machine tool imports. The number of units shipped by Japanese producers dropped by more than 30 percent. Domestic industry benefited by roughly \$80 million in additional shipments because of the VRAs, or about 3.5 percent of total shipments; this sales gain generated an estimated additional \$6 million in profits.

Japanese companies appear to have broadened their export categories to include items not covered by the VRA. They have also increased production in their U.S. factories, so that some portion of the increased domestic shipments and profits accrued to Japanese companies operating in the United States.

Machine tool exports had been restricted by U.S. law and regulation from the Soviet Union and Eastern Europe, about one-half of the world market outside of the United States. In 1982, U.S. producers shipped only 12 machines, valued at \$1.3 million, to the Soviet Union. During this same period, Japan and Switzerland each annually shipped machines valued at more than \$100 million, West Germany supplied the East Bloc with \$350 million–\$500 million, and France's exports reached \$100 million in some years. If the United States were able to maintain the same share of East Bloc trade as it does of global machine tool trade, the country would be exporting over \$100 million, \$75 million–\$80 million more than its current shipments. These lost sales represent roughly \$5.5 million–\$6.0 million lost profits.

Trade adjustment assistance, comprising cash payments, training, job search and relocation allowances, and employment services, had been available upon a finding by the Secretary of Labor that increased imports were a "substantial cause" of unemployment of a significant number of a firm's employees. In 1982, machine tool industry employment fell and 31 companies sought assistance for 2200 employees. Seven of these petitions were approved, covering 953 employees. The total value of benefits was estimated at under \$5 million. Trade adjustment assistance, therefore, did not appear to have a substantial effect on the overall welfare of unemployed machine tool workers.

The major nontrade-related government program affecting machine tools is the Defense Department's ManTech program, which contributed \$100 million–\$200 million annually to manufacturing developments in the 1980s. Total funding from 1978 to 1990 was approximately \$2 billion. Other research efforts are mounted by the National Bureau of Standards, the National Science Foundation, and by other government laboratories. Each of these sources of funding contributed roughly \$5 million annually in the mid-1980s.

### **OTHER GOVERNMENT POLICIES**

Broad macroeconomic policies affect the industry more profoundly than the trade-related and other targeted programs. Industry leaders cite aggregate economic demand, the value of the dollar, and interest rates as the most important problems facing the industry. Insufficient financing, however, stands out as a constant concern. Financing is at the core of the industry's ability to adapt to competitive challenges, which inevitably require capital. Capital problems could arise from general insufficient savings in the economy, or from biases or imperfections in capital markets that affect small manufacturing companies. Comparisons with Japan indicate that Japan has created specialized banks, credit associations, and government lending agencies designed to support small business, an industrial equivalent of the American savings and loan system designed to support the U.S. housing market. This study has not conducted independent research into the validity of the capital insufficiency hypothesis.

### **TECHNOLOGY AND THE JAPANESE CHALLENGE**

Despite the many blows at the U.S. machine tool industry, a counterargument could be made that worldwide demand was growing sharply, that hundreds of small firms were raising capital in the biotechnology industry, and that machine tool companies had faced cyclical downturns for 125 years. New challenges, though, arose from the competitive forces of developing countries, which invaded the mature technology part of the market, and from Japanese companies, which introduced new models of numerical control and computer numerical control machines.

The key factor in the Japanese success was the design of lower performance, smaller, simpler, less expensive models targeted at small machine shops and manufactures. A fiercely competitive domestic market drove the Japanese companies to



find profitable new markets and to reduce costs. They emphasized standard models with simplified controls that could be produced at high volumes; later, standardized modular components, which could be assembled in a wide range of models and styles, produced model flexibility. The strategy was implemented by risky investments in production capacity. Although the Japanese Ministry of International Trade and Industry (MITI) promulgated policies for the machine tool industry that emphasized firm consolidation, coordination of production, and collaboration to control capacity expansion, apparently MITI's policies were not successfully implemented.

The U.S. response to this challenge was weak and cannot be explained by monopoly sluggishness or by small firm size: Scores of companies produce in each product sector; and small firms, as a class, are more innovative than large firms. Genuine puzzles remain to confound our understanding of competitive markets.

## CONTENTS

PREFACE .....	iii
SUMMARY .....	v
FIGURES AND TABLES .....	xiii
Section	
I. TRENDS IN THE U.S. MACHINE TOOL INDUSTRY .....	1
Long Run Trends .....	1
Foreign Trade .....	4
Employment .....	6
II. THE STRUCTURE OF THE MACHINE TOOL INDUSTRY .....	9
Expectations from Economic Theory .....	9
Industry Size .....	11
Size of Machine Tool Establishments .....	11
Economies of Scale .....	12
Mergers and Acquisitions .....	14
Disintegration of Production .....	17
The Technology of Supply and Demand .....	20
III. GOVERNMENT POLICIES AFFECTING MACHINE TOOLS .....	22
Import-Export Policies .....	22
Export Controls .....	28
Trade Adjustment Assistance .....	29
Nontrade Related Machine Tool Programs .....	30
Summary .....	34
IV. NONSPECIFIC POLICIES AFFECTING THE MACHINE TOOL INDUSTRY .....	36
Macroeconomic Policies .....	36
Problems in Finance and Capital .....	37
V. FURTHER SPECULATIONS ON THE DECLINE OF THE U.S. MACHINE TOOL INDUSTRY .....	44
The Clear and the Fuzzy Reasons for Decline .....	44
The Japanese Challenge .....	44
American Responsiveness .....	47
BIBLIOGRAPHY .....	51

## FIGURES

1. Indices of real U.S. industrial production, investment in plant and equipment, and machine tool shipments . . . . .	2
2. Consumption, employment, and import share of consumption . . . . .	3
3. Ratios of consumption to manufacturing output and equipment investment . . . .	4
4. Labor productivity in the U.S. machine tool industry and in total manufacturing .	7
5. Machine tool establishments by employee-size categories. . . . .	13
6. Percentage distribution of employment by establishment size . . . . .	15
7. Ratio of value added to shipments. . . . .	20
8. East bloc machine tool trade—U.S. share, and share of world trade . . . . .	29

## TABLES

1. Percentage distribution of establishments by employee-size categories . . . . .	12
2. Mergers and acquisitions transactions in U.S. industry and machine tool companies . . . . .	16
3. Changes in imports, 1986 to 1987, as influenced by restrictions from voluntary trade agreements . . . . .	24
4. Percentage change of imports from Japan, 1986 to 1987, for categories covered by VRA . . . . .	26
5. Percentage change of imports from West Germany, 1986 to 1987, for selected categories covered by U.S. government declarations . . . . .	27

## I. TRENDS IN THE U.S. MACHINE TOOL INDUSTRY

### LONG RUN TRENDS

The demand for machine tools, the quintessential investment good, is notably volatile. But for several decades following World War II, the customary cycle of boom and bust disguised a new feature of American industry: the slow, long-term decline of domestic demand. By the 1980s, the earlier gradual fall in U.S. machine tool production had accelerated toward an unprecedented and precipitous depression in orders, shipments, employment, and profits. Events in the 1980s had many of their origins in the preceding decades, but one new force arose to qualitatively change the nature of the industrial adjustment: the loss of export markets and the rapid growth of imports.

Not only are machine tools a primary input in the production process, but they are used to produce other investment goods. As a consequence, they suffer a double effect of the classical accelerator principle. The swings in machine tool orders are magnified versions of the rises and falls of general economic demand and of industrial investment. Figure 1, which plots indexed values of industrial production, investment in producers' durables, and machine tool shipments, graphically depicts the volatility of the market.<sup>1</sup> The rate of return earned by machine tool companies as measured by the ratio of total net income before taxes of all companies to total assets of all companies averaged 10.3 percent over the 16-year period 1967–1982; a measure of the volatility of the average rate of return is the standard deviation of the time series, which was 6.6.<sup>2</sup> The machine tool industry's rate of return is highly correlated over time with a broader market portfolio; for example, the average return for all manufacturing was 10.2 percent, but its standard deviation was only 1.6.

---

<sup>1</sup>Unless otherwise noted, figures cited in this document are taken from various issues of *The Economic Handbook of the Machine Tool Industry*, published by the NMTBA, The Association for Manufacturing Technology (formerly the National Machine Tool Builders Association). The most recent handbook, dated 1988–1989, includes data through 1987. The Association's monthly release of January 30, 1989 provides basic order and shipment data through the end of 1988.

<sup>2</sup>The selection of these years as endpoints avoids the untypically severe downturn of 1983–1986. If the calculation were extended over the full 21 years from 1967 to 1987, the mean percentage return (and standard deviation) would be 7.4 (8.1) for machine tools, and 9.6 (1.8) for all manufacturing.

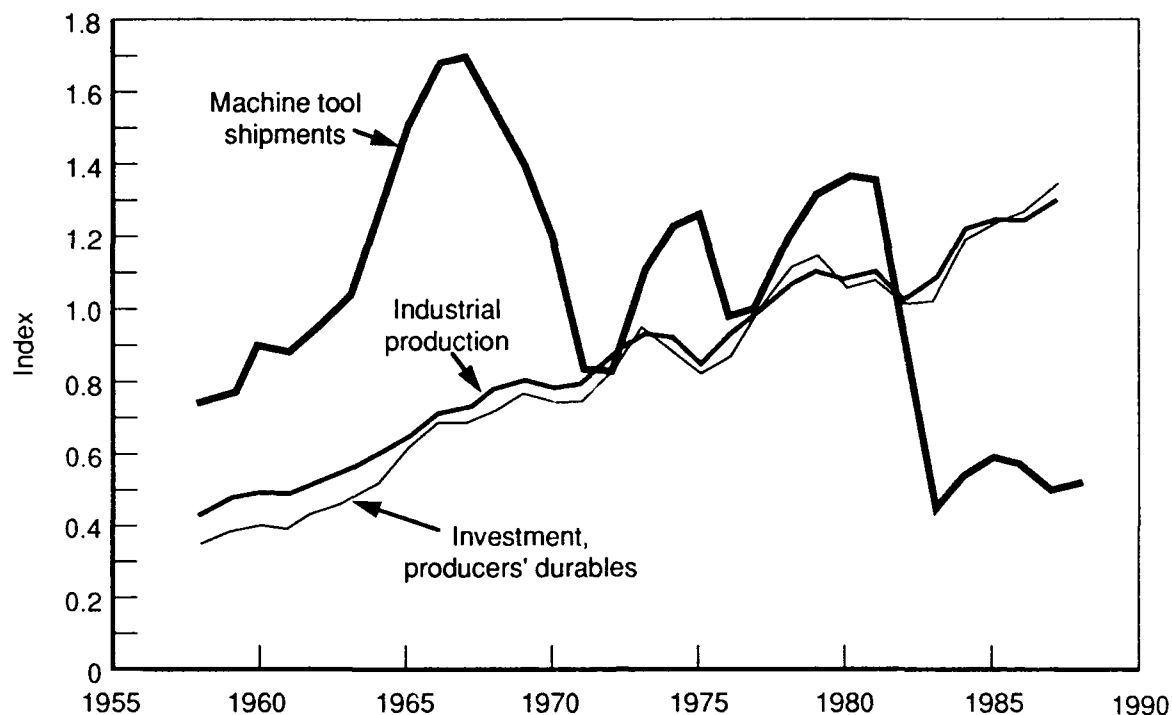


Fig. 1—Indices of real U.S. industrial production, investment in plant and equipment, and machine tool shipments (1977 = 1.00)

Similarly, net income before taxes as a proportion of sales of the machine tool companies is quite like that of all manufacturing companies, but with a standard deviation about five times greater; for the period 1967 to 1982, the machine tool ratio of income to sales was 7.35 percent and 4.7 standard deviation versus 7.46 and 0.84 for all manufacturing.

The wide cyclical movements obscure longer term trends in demand and production. As shown in Fig. 2, U.S. machine tool consumption has fallen slowly when measured by the cycle-to-cycle peaks; the most recent cyclical high point, reached in 1980, is 8 percent lower than the 1967 peak demand, despite a 50 percent growth of industrial production.<sup>3</sup> As a share of total U.S. production and investment, the machine tool contribution is clearly falling. In the 1960s, machine tools were 15–20 percent of

<sup>3</sup>"Consumption," as used here, measures the purchase of machine tools by U.S. industry; it is equal to domestic shipments plus imports minus exports. This definition is different from typical economic usage as applied to durable goods, which reflects the flow of services provided by a stock of capital.

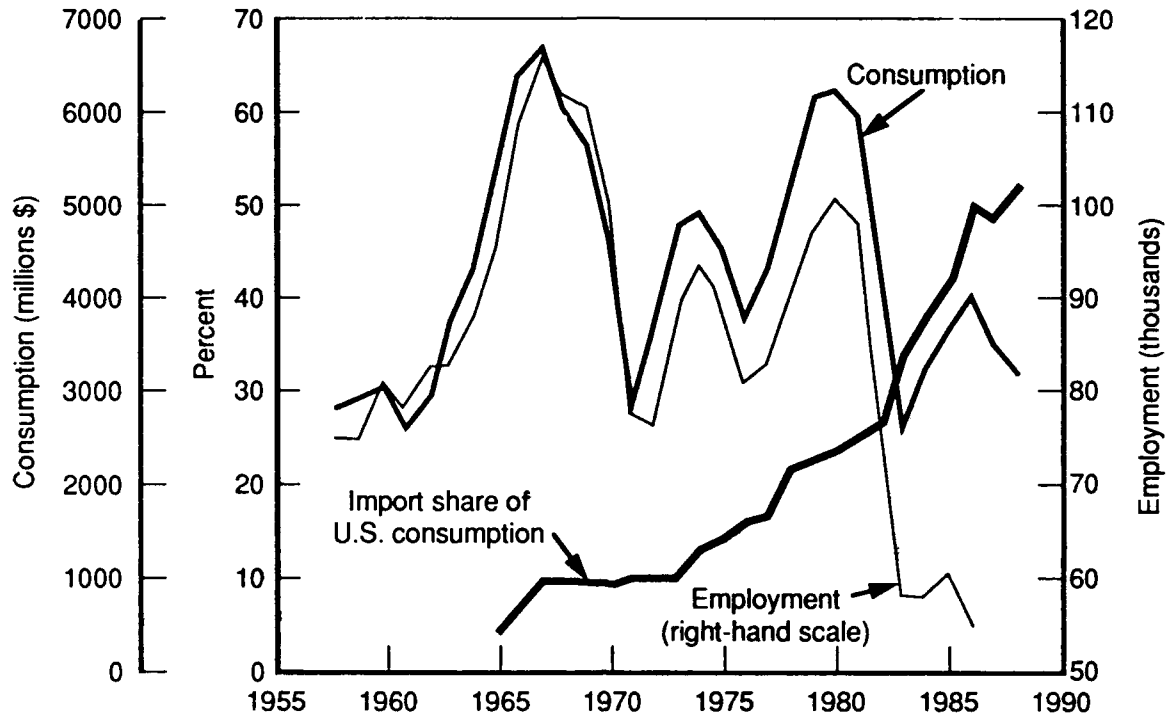


Fig. 2—Consumption, employment, and import share of consumption

the value of total equipment expenditures; this ratio fell to 10–15 percent in the 1980s.<sup>4</sup> (See Fig. 3.)

There are several explanations for the long-term decline in machine tool demand. First, machine tools are used to cut or form metal; in the past 40 years, production processes and materials have gradually made more use of nonmetallic inputs. Second, other metal forming technologies have been developed; for example, chemical milling, electrical discharge machining, precision casting, and laser cutting now substitute for many of the production jobs formerly assigned to machine tools. Third, many products that had been heavy users of machined parts are either no longer produced in large volume or are designed with nonmetallic parts; for example, railroad equipment is in long-term decline, and electronics have replaced mechanical components in calculators

<sup>4</sup>Equipment expenditures are from the Bureau of the Census and cover all manufacturing establishments (*NMTBA Economic Handbook*, p. 17); its 1986 value was \$34.5 billion.

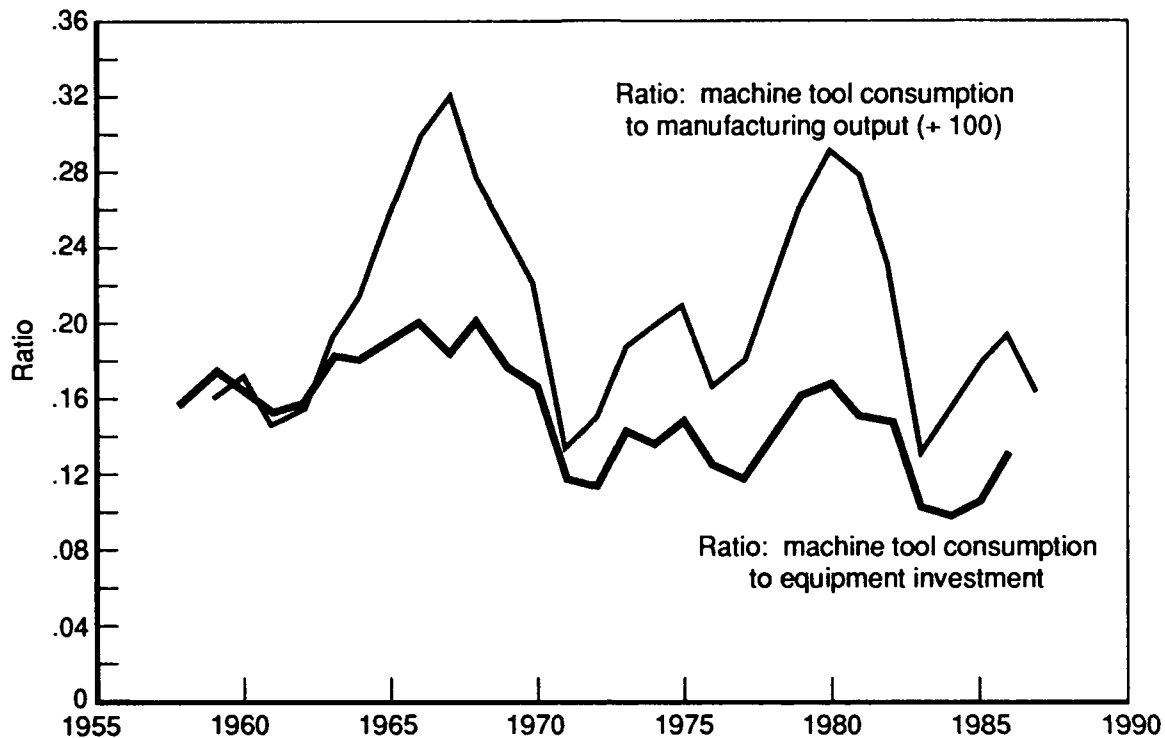


Fig. 3—Ratios of consumption to manufacturing output and equipment investment

and typewriters. Fourth, increased productivity of machine tools themselves has reduced the number of machines required by a user for a given level of output. Symbolic of this long-term decline is the 1988 name change of the industry association most closely linked to machine tools: the National Machine Tool Builders' Association became known as NMTBA—The Association for Manufacturing Technology.

## FOREIGN TRADE

In the past, cyclical downturns in U.S. machine tool demand were ameliorated by foreign demand, which was often out of phase with domestic market conditions. However, in the 1980s, the machine tool balance of trade turned sharply against U.S. producers. Historically, the United States had been a net exporter of machine tools. Since the 1860s, the names of U.S. companies were known world wide for their innovative and efficient products. This export dominance began to fade in the 1970s and by 1978 had turned into a trade deficit. (The import share of U.S. consumption is shown

in Fig. 2.) Imports supplied about 10 percent of U.S. consumption from the late 1960s through the mid-1970s. This situation then changed rapidly as import penetration grew to 25 percent by 1981 and then accelerated to a 50 percent share of domestic consumption between 1981 and 1986. For lathes, drills, and machining centers, imports supplied more than two-thirds of domestic requirements.

In the mature technology sector of the market, developing industrial nations, such as Taiwan, Korea, and Spain, were able to compete effectively with low-cost production of standard machine types, often copying 1930s vintage U.S. designs. West Germany and Switzerland, together with the United States, had dominated export markets in the high-precision, advanced technology niches. In the mid-1970s, however, Japan rapidly increased its world export market share in both the high and low ends of the market and by 1984 had overtaken West Germany as the dominant machine tool exporter.

The recent Japanese penetration of the U.S. market was facilitated by several events. Two of these events, an overvaluation of the U.S. dollar and the inability of the U.S. machine tool industry to meet peak demand in the 1979-1981 period, were short-term occurrences that exacerbated a more serious decline in the ability of U.S. companies to meet the product competition of foreign suppliers. To buffer their production from the volatility of demand, U.S. producers typically allowed the backlog of unfilled orders to increase during boom times. As orders fell during recessions, this backlog would be worked off. During times of peak demand, customers would often have to wait two or three years for delivery of their machines. However, in the 1979-1981 period, Japanese machine tool firms offered to provide immediate delivery to U.S. buyers. The availability of large stocks of machine tools enabled the Japanese producers to attract business away from U.S. suppliers. When demand subsequently turned down, the Japanese companies continued to produce machines, stocking the excess production in U.S. warehouses; this stock of product on the shelf allowed the Japanese companies again to provide immediate delivery when demand began to revive in 1984.

Both the U.S. and Japanese strategies are designed to even out production. In the U.S. approach, the customer pays for his volatile demand through delayed delivery. The Japanese strategy incurs the capital costs of stockpiled inventories (a portion of which will probably be passed on to buyers) as well as the risk of low demand for the stockpiled



models.<sup>5</sup> The choice of this alternative strategy is influenced by the cost and availability of capital. A Japanese product strategy that emphasized standard models reduced the risk of low demand for out-of-date models in contrast to the U.S. marketing approach that was oriented more toward tailored designs. A more severe challenge to the U.S. industry came from Japanese introduction of a new class of machine tools. Japanese companies introduced simplified, standardized, numerically controlled (NC) machines that did not aim at the high-performance NC niches favored by U.S. machine tool companies, but instead were directed toward the more numerous, low-tech machine shops. These NC lathes, milling machines, and machining centers<sup>6</sup> used standardized controls that were more reliable, less complex, easier to use, and less expensive than American products. By the mid-1980s, Japanese producers dominated the U.S. market in low-end NC machine tools. Since much of the growth in the United States was in this market segment—the rest of the market was stagnant or declining—Japanese sales appeared especially menacing to the beleaguered U.S. industry.

## EMPLOYMENT

As shipments of the domestic industry have fallen, employment has also declined from the peak postwar level of 125,000 reached in 1952 during the Korean War. In 1980, employment reached a high of 100,000 but then fell to a historic low of half that level only seven years later. However, an increasing share of components is being purchased from outside the machine tool industry—electronic controls being a prime example. The reported values, therefore, are an understatement of the total employment attributable directly to machine tools; this understatement appears to be growing over time. Nevertheless, in just the two years from 1981 to 1983, employment in the narrowly

---

<sup>5</sup>In the late 1930s, to avert employee layoffs IBM pursued a strategy similar to that of the Japanese machine tool producers. This gamble paid off when the new Social Security Administration chose IBM to supply punched-card calculating machines, partly because it was the only source of immediate delivery.

<sup>6</sup>Machining centers are numerically controlled machine tools with automatic tool changers that can perform many of the functions that had been customarily assigned to separate machines, such as lathes and milling machines. Machining centers can often accomplish all of the metal-cutting operations on a complex part in a single setup, a task that formerly required several machines, plus the additional and costly setups, inspections, and parts transfers between machines.

defined core industry fell by 40,000 people, a drop that led to political demands for action on imports.

Labor productivity has not demonstrated sustained growth over the years, a probable cause in itself for the declining competitiveness of the domestic industry. As shown in Fig. 4, output of value added per labor-hour rose at a 2.8 percent annual rate from 1958 to 1969;<sup>7</sup> since then it has fallen, gradually at first and then at an accelerated pace in the 1980s downturn in shipments. In 1986, labor productivity was below its 1958 value. For comparison, productivity for all U.S. manufacturing is also shown in Fig. 4. An eight-year slowdown in aggregate productivity began in 1973, but the general trend that resumed in the early 1980s was not reflected in machine tool industry figures.

Total factor productivity in machine tool production, adjusted for cyclical effects of capacity utilization, rose at a 2.39 percent annual rate from 1965 to 1973, but then fell 0.53 percent per year from 1973 to 1979, and by an accelerated 2.26 percent rate through



Fig. 4—Labor productivity in the U.S. machine tool industry and in total manufacturing (1977 = 1.00)

<sup>7</sup>Since a third to a half of the value of final shipments is purchased from outside the industry, a productivity measure defined as the ratio of value added to labor input is preferable to one based on gross shipments.

1982.<sup>8</sup> Bailey and Chakrabarti link this productivity fall to reduced levels of innovation in the U.S. industry. From 1971 to 1977, the number of innovations in cutting machines fell to roughly half their level of the previous seven-year period. A rapid flow of innovations after 1978, however, was unable to affect productivity because of weak demand and an inability to capitalize on technological advances because of low profitability and the intense competition of Japanese manufacturers, whose innovation rate had been continuously higher than that in the U.S. industry.<sup>9</sup> Another possible reason for the decline in measured productivity is the trend toward out-sourcing of key components. If these components require more skilled labor and more intensive capital inputs than the assembly and other operations retained in the final processing, then measured productivity levels will fall. However, as this process approaches long-run stability, the fall in productivity from this source should come to an end.

---

<sup>8</sup>Bailey and Chakrabarti, 1988, Table 4-2, p. 69.

<sup>9</sup>Ibid., p. 77.

## II. THE STRUCTURE OF THE MACHINE TOOL INDUSTRY

### EXPECTATIONS FROM ECONOMIC THEORY

The theoretical literature addressing declining industries is not large, but some insights flow from the few studies addressing the issue. In 1950 Joseph Schumpeter underlined the basic notion of change in a dynamic economy, in which "a process of mutation . . . incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating the new one."<sup>1</sup> Schumpeter noted that these changes embodied new methods of production and new forms of industrial organization, precisely the forces and processes at work in the machine tool industry today. Schumpeter's ideas prefigure some of the broader changes occurring in the machine tool industry. The evolving new industry structure includes such elements as the disintegration and globalization of design, inputs, finance, and marketing; the increased role of specialized R&D as technological change from outside the industry impinges on traditional methods; the increased scale of some industrial processes such as R&D, finance, and marketing, while manufacturing itself appears to remain economic at fairly small levels of output.

Recent studies have analyzed the effects of long-run decline on industry structure.<sup>2</sup> One of the central conclusions of this work is that larger firms bear a disproportionate share of the burden of industry shrinkage in the absence of substantial economies of scale. Small firms and—even more—small establishments dominate the world's machine tool industry. The apparent absence of scale economies in manufacturing therefore lead us to expect that large firms will decline faster than small firms.<sup>3</sup>

A second point emerging from the analysis is that mergers of firms may be an effective method of increasing efficiency if the new firm can close some plants that are operating at low capacity and consolidate output in a smaller number of the most efficient

---

<sup>1</sup>Schumpeter, 1950, pp. 82–83.

<sup>2</sup>Unpublished RAND research by John McMillan.

<sup>3</sup>The reasoning behind this conclusion is that if the costs of maintaining plant capacity depends on the scale of capacity (it costs more to keep a large plant going than a small plant), declining demand will impose a larger profit drain on a large plant than on a smaller one.

plants. An individual firm with only a single plant cannot close it without going out of business and losing all of its past investment in product designs, marketing, technology, and human skills. The merged firm, however, can use many of these capabilities while producing more efficiently.

Recent theoretical efforts have attempted to relate observations about the changing nature of enterprise organization and management to a set of technological developments that have drastically altered the relative prices of production activities. Since many of these changes have affected the machine tool industry and its technology, this theory is especially applicable to an understanding of current developments.

Many advanced manufacturing firms have widened their product lines, shortened their product life cycles, placed greater emphasis on product quality, increased reliance on independent suppliers, and instituted a more flexible organization of work.<sup>4</sup> Milgrom and Roberts note that very often the shift to this new production paradigm involves "substantial and closely coordinated changes in a whole range of the firm's activities" rather than a sequence of small marginal adjustments.<sup>5</sup> They hypothesize that this paradigm shift is being caused by exogenous input price changes resulting from technological change, complementarities among elements of the firm's strategy, and nonconvexities arising from the indivisibilities and increasing returns associated with many of the changes and with their complementarities.

Lower relative prices are largely those arising in collecting, organizing, and communicating data, in designing and developing new products, and in managing and operating flexible manufacturing. These technological changes create multiple interactions that reinforce each other in complementary ways. The nonconvexities introduced by these changes help to explain why the successful adoption of modern manufacturing methods may not be a marginal decision.<sup>6</sup>

These observations are important to the story of the U.S. machine tool industry because the early diffusion of this new production paradigm largely took place in Japan, giving Japanese firms a competitive advantage in cost, quality, product development, and timely delivery over the slower moving U.S. industry.

---

<sup>4</sup>Milgrom and Roberts, 1990, p. 513.

<sup>5</sup>Ibid.

<sup>6</sup>Ibid., pp. 514-515.

## INDUSTRY SIZE

One of first things to strike one about the U.S. machine tool industry is its small size. U.S. machine tool consumption is only about two-tenths of 1 percent of manufacturing output. If the aggregate 1988 shipments of the entire industry (\$2.4 billion) were attributed to a single company, its rank would be only 267 in the *Fortune* magazine list of the 500 largest U.S. companies, about the same size as Revlon. Even if we considered the 1981 peak industry sales of \$5.1 billion, the industry would still only have been equal in sales to the 80th largest company. The importance of machine tools, therefore, lies not in its absolute size but rather in its central position as a means of production and vehicle for productivity improvements for the rest of industry.

## SIZE OF MACHINE TOOL ESTABLISHMENTS

The second important feature of the industry is the small size of the individual firms. In 1982, more than two-thirds of all U.S. firms producing whole machine tools or components had fewer than 20 employees, and 90 percent had under 100 employees. Out of the almost 1400 establishments, only eight had more than 1000 employees. (See Table 1 for the size distribution of establishments in the United States and other countries.) These figures are not unique to either the 1982 census year or to the U.S. experience. Data on the number of establishments by size, for 30 years, indicate no tendency for a reduction in the number of small-scale establishments (see Fig. 5). At the upper end of the size range, though, as predicted by theory, the number of large establishments of more than 1000 employees fell after the late 1960s recession in investment goods, from a high of 25 in 1967 to a low of seven in 1986. Since 1967, this decline of the largest establishments spread to those larger than 250 employees, whereas the number of small establishments of fewer than 50 employees grew. (The intermediate range of 50 to 500 employees remained stable.) Data for other countries also show few large establishments; Germany had 20 large establishments of more than 1000 employees, Great Britain had five, and Japan six.

Japan has an even larger percentage than the United States of the smaller size firms with more than 80 percent of all firms under 20 employees. In fact, in this category, the average size of the Japanese company is roughly 1.6 people: The prototypical Japanese machine tool company is an owner-operator of a numerical control machine tool and one helper supplying parts and components to a major machine tool

Table 1

PERCENTAGE DISTRIBUTION OF ESTABLISHMENTS  
BY EMPLOYEE-SIZE CATEGORIES

Number of Employees	U.S. (1982)	Japan (1980)	Italy (1983)	W. Ger. (1976)	U.K. (1980)
1-19	67.3	80.8	40.9		
20-49	14.5	9.7	27.7		
50-99	7.9	4.2	20.0 <sup>a</sup>		
1-99	89.7	94.7	89.4 <sup>b</sup>	79	
100-1000	9.7	5.0	8.5 <sup>c</sup>	19	
> 1000	1.8	0.3	2.1 <sup>d</sup>	2	1.7
Numbers of establishments > 1000	8	6	9 <sup>e</sup>	20	5

SOURCE: USITC Publication 1428, 1983.

<sup>a</sup>Size range 50-150.

<sup>b</sup>Size range 0-150.

<sup>c</sup>Size range 150-500.

<sup>d</sup>Size range > 500.

<sup>e</sup>More than 500 employees.

company. In contrast, the average size of a U.S. firm in this smallest size category is six employees.

The largest establishments in the United States with more than 1000 employees account for approximately 23 percent of the total industry work force. Comparable data on employment is lacking for Japan, but 37 percent of all shipments originate in the large companies.

## ECONOMIES OF SCALE

Because of the persistence over time and widespread nature of the small size of machine tool establishments, we can infer that economies of scale for organizations greater than 1000 employees are absent. For example, a Japanese-owned machine tool plant in North Carolina was described as highly efficient and equipped with the latest production machinery from around the world but staffed with only 150 "easily managed" employees.<sup>7</sup> A British survey of machine tool firms concluded that the most successful

<sup>7</sup>Winter, 1990, p. 1.

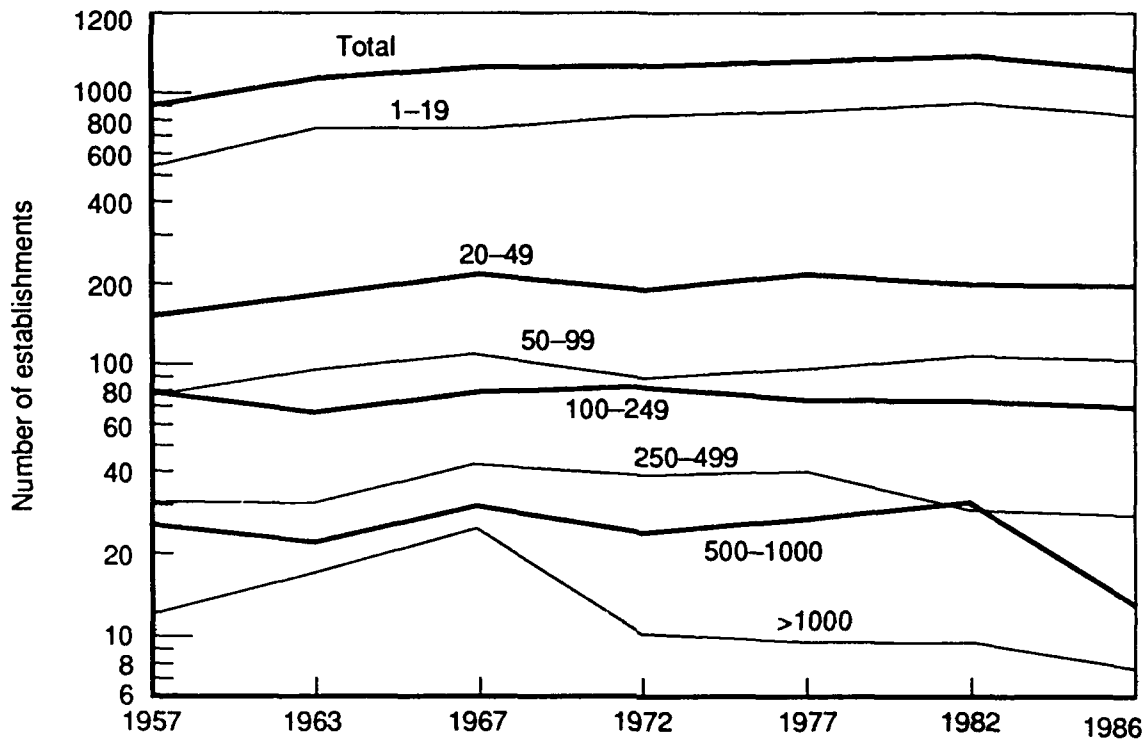


Fig. 5—Machine tool establishments by employee-size categories

of the surveyed companies regarded 500 employees as being "the maximum tolerable establishment size."<sup>8</sup> Another British study examined scale economies arising from several sources: (1) increased batch size of a given model of machine tool; (2) increased total annual production of a particular model; (3) increased firm size resulting from higher production of a fixed, narrow range of products; and (4) increased firm size from extending the range of products.<sup>9</sup> Pratten found scale effects that varied from a 22 percent reduction in costs for a doubling of output at small batch sizes and annual quantities (5 to 50 units) down to 8 percent at high volumes (100 to 800 units). Analysis of factorywide cost reductions found modest scale effects that declined with increased output; costs fell by 9 percent as total quantity increased from 800 to 1500 units, and by a further 6 percent and 5 percent for subsequent doublings of output to 300 and 600 units. Firmwide effects from extending the range of products were harder to document; indeed,

<sup>8</sup>Cited in Daly and Jones, 1980, p. 55.

<sup>9</sup>Pratten, 1970-1971, pp. 148-165.



many of the surveyed firms identified disadvantages to broader scope. Several managers claimed that factories of 200–300 employees were the optimum size. Pratten concluded that "economies attributable to larger factories appear to be small in relation to other factors affecting performance."<sup>10</sup>

Despite this evidence, a British government policy in the 1960s encouraged mergers and the creation of larger units. To further this policy, the government supplied some £45 million to enable the Alfred Herbert Company to consolidate with several smaller companies; the Herbert group grew from 6000 employees to a peak of 15,000 in the late 1960s, accounting for close to a fifth of British machine tool output. Within a few years, however, the group was on the verge of liquidation, and several subsidiaries had gone into receivership. A critical analysis of British government policy noted that no evidence had been put forth that *plants* of the size contemplated by government (and actually implemented by industry with official encouragement) were required for success in the industry. Moreover, no case was established for the advantage of large scale *firms*, with benefits arising from consolidating several establishments under a single management umbrella.<sup>11</sup>

Diseconomies to a particular size establishment should show up in the gradual diminution of the number of firms in that size group or in a decline in their aggregate share of business or employment. As mentioned above, Fig. 5, which plots the number of establishments in each size category over a period of 30 years, shows increases in the smallest categories and a sharp decline in the largest. If we consider the distribution of industry employment shown in Fig. 6, a similar picture emerges. The share of employment of the establishments under 100 employees increases by about 5 percentage points, whereas the share of the largest establishments of more than 500 employees falls precipitously by almost 30 percentage points from 1967 to 1986.<sup>12</sup>

## MERGERS AND ACQUISITIONS

Consolidation through mergers, acquisitions, and the purchase of assets is a means for altering the structure of the industry. If scale economies were important, the

---

<sup>10</sup>Ibid., p. 161.

<sup>11</sup>Daly and Jones, 1980, p. 58.

<sup>12</sup>The U.S. Census publishes combined employment figures only for establishments of more than 500 employees to prevent disclosures of individual establishment information.

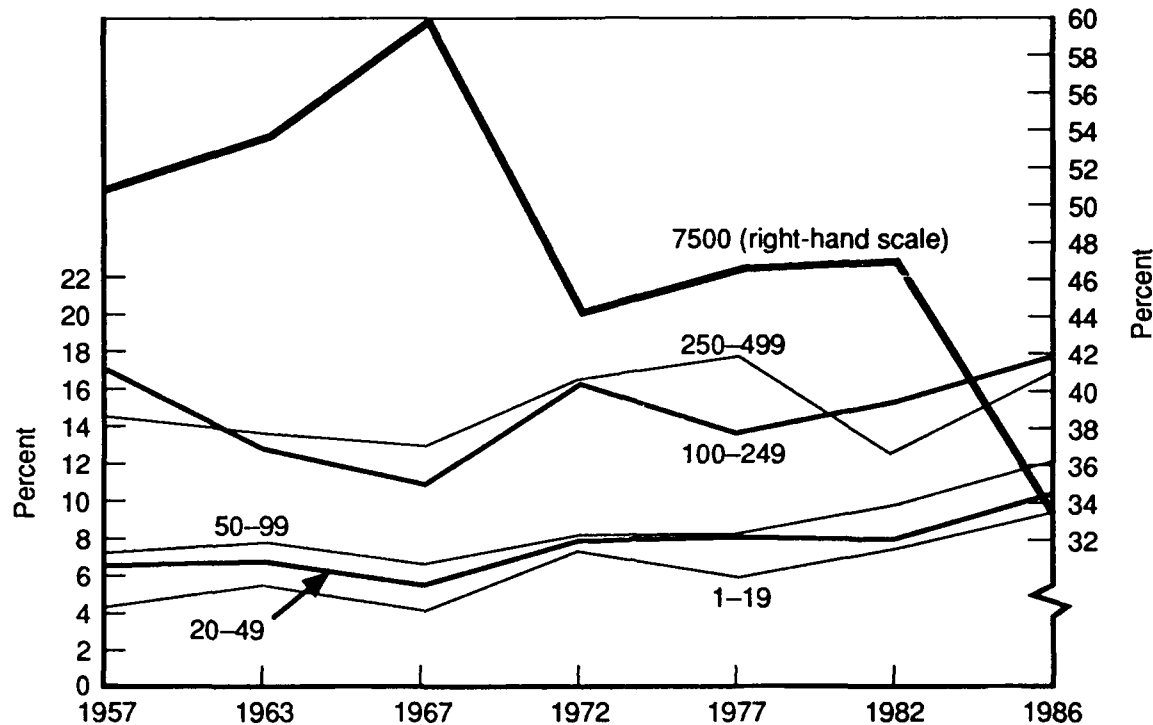


Fig. 6—Percentage distribution of employment by establishment size

incentive to engage in such activities would be especially powerful in industry downturns when inefficiencies would be most harmful. Data on mergers, acquisitions, and purchases of assets were collected by the U.S. International Trade Commission for transactions involving machine tool builders. These data are reproduced in Table 2, together with the total number of mergers and acquisitions transactions for the United States as reported in *Mergers and Acquisitions* magazine. Machine tool transactions were around ten per year, except for 1980 when 18 transactions occurred. The ratio of machine tool transactions to the total number varied within the range of .004 to .006, except for 1980 when it rose to .0115. The 1980 surge in acquisitions was probably related to profits, which were at a 20 year peak. Mergers and acquisitions at that time were undoubtedly motivated more by the attraction of the cash flow than by the possibility of improving operational economies. General merger activity throughout the

Table 2

MERGERS AND ACQUISITIONS TRANSACTIONS IN U.S.  
INDUSTRY AND MACHINE TOOL COMPANIES

Year	Total U.S. Transactions (all industries) <sup>a</sup>	Machine Tool Transactions <sup>b</sup>	Ratio: Machine Tools to Total (%)
1977	1209	8	0.66
1978	1452	7	0.48
1979	1564	10	0.63
1980	1565	18	1.15
1981	2326	10	0.43
1982	2296	11	0.48
1983	2387	10	0.42

SOURCES: <sup>a</sup>Annual totals, *Mergers and Acquisitions*, magazine, various issues, 1977-1983.

<sup>b</sup>USITC, 1983, p. 19 (extracted from Federal Trade Commission data).

economy increased by more than 50 percent in the next few years, but consolidations in the machine tool industry fell back to the earlier figures of about ten per year as industry profits sank with the level of sales

My own attempt to gather acquisition data from the pages of *Mergers and Acquisitions* yielded similar results. Although the number of reported transactions among machine tool producers was small and spotty, there was no discernible trend; approximately three to seven transactions occurred each year with an apparently random dispersion over time.

From the late 1960s to the early 1980s, several large conglomerates acquired machine tool companies, including Litton, Ex-Cell-O Corporation, White Consolidated Industries, Bendix, and Textron. Although their goals were mixed, there was a general belief that central engineering staffs, corporate level R&D, and centralized financing could overcome some of the perceived weaknesses faced by small companies in these nonmanufacturing functions. Within a few years, Ex-Cell-O was offering its machine tool subsidiary for sale; Textron sold its holdings of Bridgeport Machines, Jones & Lamson, and the Bryant Grinder Corp.; and Bendix sold its Warner and Swasey subsidiary just five years after having acquired it. Other conglomerates were also selling

off their machine tool holdings; Litton Industries divested several of its operations, and Emhart Corp. sold 16 manufacturing units specializing in machine tools.<sup>13</sup>

Some of the conglomerate owners of machine tool companies have been accused of damaging the long-run viability of the industry and destroying particular companies, primarily through lack of reinvestment.<sup>14</sup> Textron, for example, was said to have channeled the steady stream of income from Bridgeport and Jones & Lamson to other activities in the firm rather than to new machine tool developments. Over a decade-long continuation of this policy, these two Textron divisions lacked new lines of competitive products, especially in numerical control.<sup>15</sup>

In the meantime, a new kind of conglomerate emerged—the machine tool holding company. An example of this is Stanwich Partners, a venture capitalist that has acquired several machine tool companies, including the holdings of White Consolidated Industries from the Swedish conglomerate Electrolux.<sup>16</sup> Stanwich management has stated that it could use mergers and cost-cutting measures to achieve efficiencies in an industry burdened with excess capacity. It is consolidating operations of several of its U.S. acquisitions into two plants in the United States; operations of two European acquisitions are being consolidated into a single English factory. By operating fewer plants closer to full capacity, the new owners were expecting to achieve better operating efficiency. With a larger sales base and hopes of further penetration in Europe and the Far East, the company is planning on spreading its increased R&D and engineering costs over a larger revenue base and realizing economies of scope in distribution of a broader product line.<sup>17</sup> So far, the new consolidated company appears to be profitable, but it remains to be seen whether rationalization within a holding company can achieve the desired effects that have so far eluded other business and government strategists.

## **DISINTEGRATION OF PRODUCTION**

Rather than the consolidation of machine tool companies, vertical disintegration is a growing phenomenon. Vertical disintegration was a dominant form of industrial

---

<sup>13</sup>*Metalworking News*, December 15, 1986, p. 6.

<sup>14</sup>March, 1989, p. 15.

<sup>15</sup>*Ibid.*, p. 78.

<sup>16</sup>"Stanwich Sets Machine Tool Consolidation," *Metalworking News*, August 1, 1988, p. 1.

<sup>17</sup>Moskal, 1988, p. 28.

organization in Japanese manufacturing; it is now increasing elsewhere.<sup>18</sup> Competitive alternatives to internal supply are emerging in the growth of specialized suppliers worldwide of standardized machine tool components. At first, these components used different technologies than the products of the machine tool companies; electric motors, for example, were bought from specialized companies from the first days of machine tool electrification at the turn of the century. More recently, specialist firms have supplied numerical controls, computers, and software, with these items accounting for one-third of the cost of a numerical control machine.<sup>19</sup> Hydraulic control mechanisms, laser measuring devices, and electric servo-motors have replaced lead screws, gear transmissions, and handwheels; the production techniques of the lead screws and other traditional components were products of the same mechanical technologies as the main structure of the machine tool, but the newer components require an expertise and production capability unlikely to be found in a machine tool company. Moreover, specialized companies in the United States even produce some of the traditional mechanical parts: for example, high precision leadways, tables, and gears.

Design changes in the machine tools that emphasize modularity have abetted specialization of component production. Through modularity and standardized families of components, machine tools virtually custom-designed for specific customers can be assembled from components available in a wide range of sizes and capabilities.

Many of the Japanese machine tool producers were among the first to grasp the nature of modularity. Their strength had earlier been in the production of standardized models, which allowed Japanese companies to gain the benefits of economies of scale; American companies tended to emphasize custom-built machines. The introduction of modular designs allowed Japanese companies to combine the advantages of scale economies and tailor-made products.<sup>20</sup>

This disintegration and globalization process is illustrated by a Japanese machine tool company's U.S. plant installing controls on turning centers that were manufactured

---

<sup>18</sup>This point is made by Rendeiro, 1985, p. 63. Friedman, 1988, Ch. 4, also analyzes this issue.

<sup>19</sup>"The Vise Tightens on Toolmakers," *Business Week*, December 6, 1982, p. 63.

<sup>20</sup>March, 1989, pp. 35, 40, 109. Japanese lathe producers, for example, were building 50-200 computer numerical control lathes monthly, whereas U.S. companies produced in the range of 15-40.

in a French joint venture, which uses a composite-based machine bed licensed from a Swiss concern.<sup>21</sup>

In interviews with U.S. companies acquired by Japanese owners, U.S. managers said that the major production change introduced by the new owners was the subcontracting of complex or specialized components. When questioned by their new owners as to why they continued to manufacture such components as gears, respondents said that their only reason was habit—they had done it that way for a hundred years.

This pattern of "out-sourcing" is illustrated by the Bendix Corporation's strategic plan for its machine tool acquisitions. To meet worldwide competition, "the emphasis within the Group would be on design and assembly of superior products, with most of the technological development and manufacturing sourced from outside."<sup>22</sup>

Bendix's strategic view is echoed in an analysis of the implications of vertical disintegration. According to this analysis, producers of complete machine tools are likely to become more of an "R&D and assembly house," rather than a manufacturing concern.<sup>23</sup> With global competition, price will dominate the components business, and integrated manufacturing will probably suffer a cost disadvantage. Nevertheless, manufacturing will remain vitally important at the component level.

One measure of vertical disintegration is the ratio of value added to sales. If every firm in the industry were totally integrated, producing everything from raw materials to finished product, this ratio would be equal to one. As operations are contracted to other companies, the ratio falls; and as the sources are found in companies outside the machine tool industry, the ratio would fall even further. This ratio is plotted in Fig. 7. From 1958 to the late 1970s, the ratio of value added to sales at the cyclical peaks was about 0.66, falling to 0.59 during industry recessions. Since the 1980s, however, both the peak and trough values have declined, with an all-time low value of 0.52 reached in 1986—a year of partial recovery. The data are therefore consistent with the model of vertical disintegration within the machine tool industry.

To the extent that vertical disintegration draws increasingly on sources outside the industry boundaries defined by the Standard Industrial Classification (SIC), a statistical

---

<sup>21</sup>"Japanese Tool Builders Little Affected by VRAs," *Metalworking News*, June 19, 1989, p. 20.

<sup>22</sup>Harvard Business School, *Case Study: Bendix Automation Group*, 9-684-035, 1983, p. 5.

<sup>23</sup>Rendeiro, 1985, p. 63.

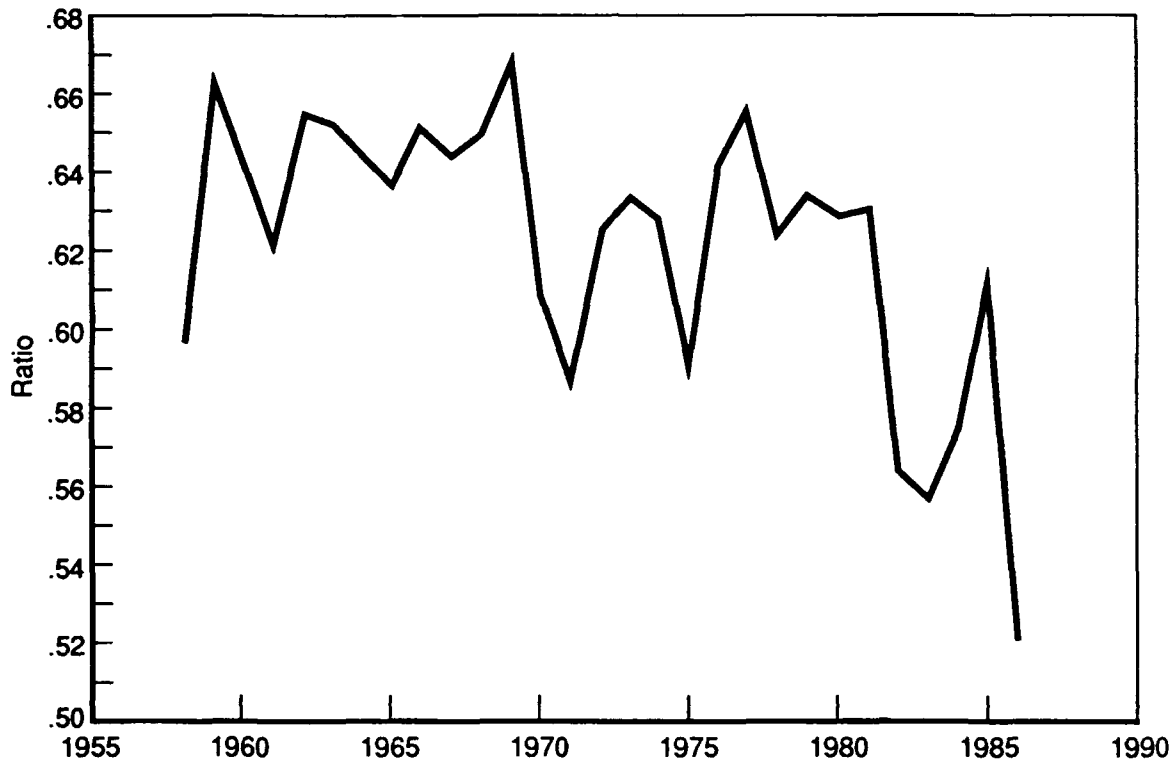


Fig. 7—Ratio of value added to shipments

view of the industry may become a distorted vision of what is actually happening. The number of reported employees, companies, establishments, and profits could easily undercount the totals and bias understanding of events, as companies in the electronics industries and other manufacturing industries become more important suppliers to machine tool producers. Beyond the machine tool industry, other types of metal forming and nonmetallic materials processing must also be taken into account for a fuller understanding of manufacturing processes.

#### THE TECHNOLOGY OF SUPPLY AND DEMAND

Technological change was transforming the machine tool industry in the 1970s and 1980s. NC and then the introduction of micro-processors in computer numerical control (CNC), computer-aided design and manufacturing (CAD-CAM), modularity in

design and production, and specialization and disintegration all gradually evolved during this period. These technological changes were accompanied by the ability to produce machine tools in most of the developed and industrializing countries. The technological changes favoring flexibility in design, development, production, and marketing were reinforced by the emergence of worldwide competition; in concert, these changes led to shorter product cycles, faster and more responsive product developments, a technological capability as well as a market push for speedier order delivery, and an increased importance of R&D in nontraditional areas such as software and controls.

With these changes, standardized (but modular) NC machine tools were increasingly able to dominate market sectors that at the low production end were formally the realm of general-purpose machine tools and at the high-production-rate segment of the market were the home of special-purpose, high volume manufacturing machines. The general introduction of NC and CNC brought flexibility and high rates of machine utilization, as well as a host of other benefits: for example, higher output quality, lower rejection rates, reduced inspection time, faster throughput, smaller inventories, fewer in-process parts, and less need for storage and in-plant conveyor capabilities.

To take full advantage of these changes, firms had to totally reorganize their methods of production, R&D, and management of customer orders. As more customers of the machine tool companies made these changes, their demand for flexible production machinery, fast delivery times, and high quality inputs helped to fuel the process for change in the machine tool producers. Japanese companies and the Japanese machine tool industry adapted to these changing conditions a decade or more before U.S. industry.<sup>24</sup> Thus, by 1983, the number of NC/CNC machines was only 5 percent of the installed machine tool base in the United States, versus 30 percent in Japan. Most of these American machines were in larger companies, with less than 20 percent in the shops of fewer than 20 employees; in Japan over 25 percent of NC/CNC sales were to companies with under 10 employees. By the 1980s, not only was the U.S. machine tool industry suffering from long-term secular decline and an overvalued dollar, but it was also caught short in product technology and management innovation.

---

<sup>24</sup>For a more detailed discussion of this subject, see Alexander, 1990.



### **III. GOVERNMENT POLICIES AFFECTING MACHINE TOOLS**

#### **IMPORT-EXPORT POLICIES**

U.S. trade laws and regulations provide several avenues of relief to industries and companies suffering declines brought about by import competition. The arcane workings of the law in the foreign trade area permit relief to be sought on different grounds: Section 201 governs relief from serious injury caused by import competition; section 301 responds to "unfair" foreign trade practices; countervailing duties may also be requested, which are intended to deal with the dumping of goods at unfair prices. These laws and others are administered according to standardized procedures in open hearings where rebuttals and counterarguments are often pursued. The various statutory provisions for trade relief require a showing that the domestic industry has suffered injury caused by imports; some require that nations or foreign companies have engaged in unfair trade practices or market manipulation.

By contrast, relief under section 232 (the National Security Clause) is mandated whenever it is shown that imports "threaten to impair the national security." It is not necessary to demonstrate unfair practices, or even that imports caused the conditions in the affected industry; the clause only requires showing that imports would impair national security, given the condition of the industry.

In addition to the above sections of the U.S. trade law, section 103 of the Internal Revenue Code provides for suspension of the investment tax credit to buyers of articles produced in a foreign country that engages in discriminatory acts or cartel behavior.

In May 1982, Houdaille Industries, a leading machine tool producer, filed for relief under section 103; and in March 1983, the NMTBA submitted a petition under section 232 on behalf of its members.

There was some speculation as to why Houdaille relied on section 103, since, even if relief were granted, it would have affected the price of the imported products by only small amounts. One observer conjectured that Houdaille hoped to avoid the rigid standards established by the other regulatory procedures. Section 103 was an obscure clause in the tax law with little or no precedent for procedures and process; with this

approach, it may have been possible to establish new precedents and standards.<sup>1</sup> Houdaille may also have been engaging in strategic behavior where it hoped that its petition, and perhaps others like it, would stimulate a Japanese government response to control exports through preemptive voluntary restraints.

The Office of the Special Trade Representative rejected the Houdaille petition in its entirety in April 1983. This rejection may have been due to an intervention by Japanese Prime Minister Nakasone, as asserted by the trade press at the time. Or it may have been that Houdaille could not support its case of cartel behavior, subsidies, and market manipulation. Scholarly examination of these issues has indicated that the allegations had little substance.<sup>2</sup>

The NMTBA section 232 petition, however, was accepted in March 1986, only the second case to win approval under the National Security Clause. The Secretary of Commerce found that imports represented a threat to national security in seven of the 18 product categories mentioned in the petition: machining centers, vertical and horizontal NC lathes, non-NC lathes, milling machines, and NC and non-NC punching and shearing machines. Rather than issuing unilateral presidential directives to control imports, the administration sought voluntary import restraints (Voluntary Restraint Agreements or VRAs) from the important export countries: Japan, Taiwan, Germany, and Switzerland. Japan and Taiwan formally signed VRAs to limit NC machines to their 1981 U.S. market share, and non-NC machines to their 1985 share. Germany and Switzerland refused to sign such agreements but were informed that their exports of a subset of the restricted machines must not exceed their market shares for the same years—1981 and 1985. Additionally, the VRAs specified that the product mix within categories would be maintained to prevent shifts into higher-valued product lines, a move often observed when quantitative restrictions were placed on other products.<sup>3</sup> These restrictions became effective on the first day of 1987.

To assess the effects of the VRAs on the American machine tool industry, Table 3 compares the change in U.S. import quantity, value, and price of the restricted items with

---

<sup>1</sup>These speculations are described in Saxonhouse, 1986, p. 224.

<sup>2</sup>Saxonhouse, 1986, pp. 225–227; also see Friedman, 1988, Ch. 3.

<sup>3</sup>As part of a policy package associated with the VRAs, the government announced several other measures, including more favorable opportunities for the machine tool industry to obtain funding from the Defense Department's ManTech program and federal support of a new National Center for Manufacturing Sciences.

Table 3

CHANGES IN IMPORTS, 1986 TO 1987, AS INFLUENCED  
BY RESTRICTIONS FROM VOLUNTARY TRADE AGREEMENTS

Categories	Units		
Restricted <sup>a</sup>	-27.8	+16.6	-15.8
Unrestricted	-12.8	+6.3	-7.3

<sup>a</sup>Machine tools priced over \$2500.

imports of unrestricted items between 1986 and 1987. The VRAs had an apparently sharp effect as the import quantity of restricted products fell by almost 28 percent, compared with a 13 percent fall in all unrestricted goods. The same result is shown in value terms, where the restricted items fell by almost 16 percent, more than twice the decline of the unrestricted categories. An important side effect is the change in average price: For the products covered by the VRAs, prices rose an average 16.6 percent, whereas they rose only 6 percent for the unrestricted machines.<sup>4</sup>

For the individual product categories covered by the VRAs, both the number of imported units and the value of imports fell in each category. Price increases tended to be highest in the NC items, and negative or low in the non-NC categories.

The VRAs had their intended effects, though perhaps at the cost of significant price increases in the restricted categories, unless importers were successful in shifting their product mix to higher-priced units, which was prohibited by the agreements.

If in the absence of VRAs the value of imports of restricted items had fallen at the same rate of decline of 7.3 percent as the unrestricted items, rather than the 15.8 percent decline actually observed, imports would have been roughly 8 percent higher than they actually were.<sup>5</sup> Domestic industry therefore benefited by roughly \$80 million in additional shipments because of the VRAs, or about 3.5 percent of total shipments. This

<sup>4</sup>The aggregate figures do not allow the determination of whether the average price increase per unit arose from actual increases in prices of comparable machines, or from the substitution of higher priced units in place of simpler, lower priced products.

<sup>5</sup>The declining value of the dollar during this period was beginning to have a retarding effect on U.S. imports.

gain in sales could have generated an additional \$6 million in profits, at the long-run ratio of profits to sales.<sup>6</sup>

The U.S. International Trade Commission (USITC) has also estimated the 1987 effects of the machine tool VRAs. According to the USITC analysis, elimination of the VRA quotas would have allowed the value of total imports to rise by \$126 million, or 13.8 percent.<sup>7</sup> Price increases as a result of the VRA quotas were estimated at 4.4–4.9 percent. The USITC calculated the U.S. employment benefits of the quota at 658–671 workers. The major difference between the USITC estimate and my own is that they apparently did not take into account the decline in total imports; they therefore would have overestimated the effects of the VRA quotas.

These falls in imports of the VRA categories could also have been caused by particularly weak demand for these particular products. However, the import *share* of U.S. consumption of the restricted categories also fell an average ten percentage points (ranging from a 1.5 percent fall for machining centers to 14.8 percent for punching and shearing machines). For all of U.S. machine tool consumption, though, imports barely changed their rate of penetration, falling a scant 0.7 percentage points from 49.4 to 48.7 percent. Therefore, the lower imports of VRA items represented a real loss of U.S. market share.

The reduced pressures from Japanese products could also have been caused by booming demand for machine tools in the domestic Japanese market. By mid-1989, home demand was said to be so great as to reduce the availability of units for export.<sup>8</sup> In three out of the six restricted VRA product categories, Japanese exporters filled only about 50 percent of their ceilings; all of the non-NC categories were underfilled.<sup>9</sup> This evidence is consistent with high Japanese demand, or over-zealous policing of quotas, or a shift to the more expensive NC machine tools.

Japan and Taiwan signed formal VRAs with the United States, whereas Germany and Switzerland were placed on notice that their imports into the U.S. would not be

---

<sup>6</sup>The Department of Commerce had projected a decline of value of \$155 million from the VRAs in 1987, under the assumption that demand and imports would remain constant. The estimate in this Note takes into account the fact that imports of unrestricted items actually fell by more than 7 percent. See U.S. Department of Commerce, 1986, p. 2.

<sup>7</sup>Rousslang and Pollard, 1989, Table 3-14, p. 3-16.

<sup>8</sup>Jones, 1989, p. 20.

<sup>9</sup>Rousslang and Pollard, 1989, Table 3-13, p. 3-15.

allowed to exceed certain specified limits. Import data for Japan and Germany allow us to test the effects of these two procedures. Table 4 shows U.S. imports from Japan for the metal-cutting sector of the market, which includes three of the restricted categories: lathes, milling machines, and machining centers (comparable data on punching and shearing machines are not provided in the NMTBA handbook). The number of units of the restricted categories shipped by Japanese producers to the United States dropped by more than 30 percent, more than twice the decline of unrestricted categories. In value terms, the decline relative to unrestricted items was even greater: a 26.5 percent fall for VRA items versus a 1.8 percent drop in other shipments. (U.S. government estimates had projected a 20.6 percent decline in value.)<sup>10</sup>

The German data, shown in Table 5, are mixed. German information is available only for lathes and punching and shearing machines. The shipment of lathes to the United States actually rose by 15.5 percent (rather than a U.S. projected increase of 13 percent), whereas punching and shearing machines fell by 7.6 percent (16 percent projected). The U.S. import value of all other German machine tools fell by about 8 percent. The evidence does not show unambiguously that the U.S. trade restriction policy affected German behavior in the absence of a formal VRA.

Despite the attempts in the VRA language to prevent exporters from working around the restrictions, experience with other kinds of ceilings and limits suggests that

Table 4

PERCENTAGE CHANGE OF IMPORTS FROM JAPAN, 1986 TO 1987,  
FOR CATEGORIES COVERED BY VRA

Category	Units	Price	Value	Commerce Dept. Estimate of Effects on Value
Lathes	-28.2	+9.8	-21.3	-10.5
Milling machines	-30.2	+105.7	+42.3	+30.0
Machining centers	-39.9	+9.9	-34.0	-28.4
Restricted categories	-32.5	+9.0	-26.5	-20.6
Unrestricted categories	-13.2	+13.6	-1.8	

<sup>10</sup>U.S. government projections were given in the "Data Fact Sheet" attached to the *Statement by the President*, Office of the Press Secretary, December 16, 1986.

Table 5

PERCENTAGE CHANGE OF IMPORTS FROM WEST GERMANY,  
1986 TO 1987, FOR SELECTED CATEGORIES COVERED  
BY U.S. GOVERNMENT DECLARATIONS

Category	Value	Commerce Dept. Estimate of Effects on Value
Lathes	+15.5	+12.9
Punching and shearing	-7.6	-16.4
Restricted categories	+7.1	
Unrestricted categories	-8.1	

shifts and adaptations can be expected that will minimize the effects of the restrictions. The machine tool trade press has noted that Japanese companies have broadened their product offerings to include categories not covered by the VRA. Executives of U.S. operations of Japanese companies, for example, explicitly noted that the VRA was a main reason for their introduction of grinders and screw machines into the U.S. market.<sup>11</sup> Import statistics confirm that market penetration of imported grinders rose from 35 to 40 percent between 1986 and 1987. Out of 11 broad machine tool categories, the four restricted categories all lost U.S. market penetration share, whereas four of the unrestricted categories gained and three lost.

Another method of adapting to import restrictions has been for Japanese firms to increase production in their U.S. factories. Hitachi Seki, Mitsubishi Heavy Industries, and Yamazaki Mazak all expanded U.S. production. Total production by Japanese companies in the United States will be about 5000 units in 1990, up about 40 percent over 1989.<sup>12</sup> These moves have led to a quiet dispute between the U.S. and Japanese governments and industries as to what constitutes an import, and what is "Made in the U.S.A." In early 1989, the U.S. government proposed that of the 21 major components in typical machine tools, more than 11 must be procured in the United States; the 11

<sup>11</sup>"Japanese Broaden Range of Machine Tools Sent to U.S.: Led by non-VRA Grinders, Screw Machines," *Metalworking News*, September 19, 1988, p. 4.

<sup>12</sup>"Help is on the Way for U.S. Toolmakers," *Japan Economic Journal*, May 26, 1990, p. 22.

components must include ten "key" items, including numerical control and spindles.<sup>13</sup>

The necessity for writing regulations of this specificity and detail demonstrates the ability of companies to work around formal restrictions.

## EXPORT CONTROLS

U.S. machine tool exports are restricted by export administration regulations and foreign policy controls from about one-half of the world market outside the United States. The Soviet Union and Eastern Europe, as a bloc, have imported approximately \$1 billion per year since the mid-1970s, rising to \$2 billion in the late 1980s. During the peak of the détente period with the USSR, the United States managed to gain 10 percent of this market. However, with the cooling of political and economic relationships, especially following the Soviet invasion of Afghanistan, U.S. sales fell to barely 1 percent of East bloc imports; in 1982, U.S. producers shipped only 12 machines, valued at \$1.3 million, to the Soviet Union. During this same period in the early 1980s, Japan and Switzerland each shipped more than \$100 million annually, West Germany supplied Eastern Europe and the Soviet Union with \$350 million–\$500 million in machine tools each year, and France's exports were three to five times the U.S. value, rising to over \$100 million in selected years. The machine tool industry in the United States naturally complains of stringent controls that place it at a competitive disadvantage, especially since the trade restrictions appear to have little effect on the ability of the Soviet Union and its allies to import what they desire.<sup>14</sup>

Figure 8 shows the U.S. share of East bloc machine tool imports, the U.S. export share of world trade in machine tools, and the real (1982 dollars) value of shipments to the USSR and Eastern Europe. If the United States were able to maintain the same share of East bloc trade as it does of global trade (around 5 percent in recent years), the United States could be exporting over \$100 million—\$75 million–\$80 million more than its current shipments. These lost sales represent roughly \$5.5 million–\$6.0 million in lost profits.<sup>15</sup>

---

<sup>13</sup>"US Seeks Higher Local Content in Machine Tools," *Japan Economic Journal*, April 1, 1989.

<sup>14</sup>In particular, see Testimony of James Gray, *NMTBA Petition*, 1983.

<sup>15</sup>This estimate assumes a marginal profits to sales ratio of 7.4 percent.

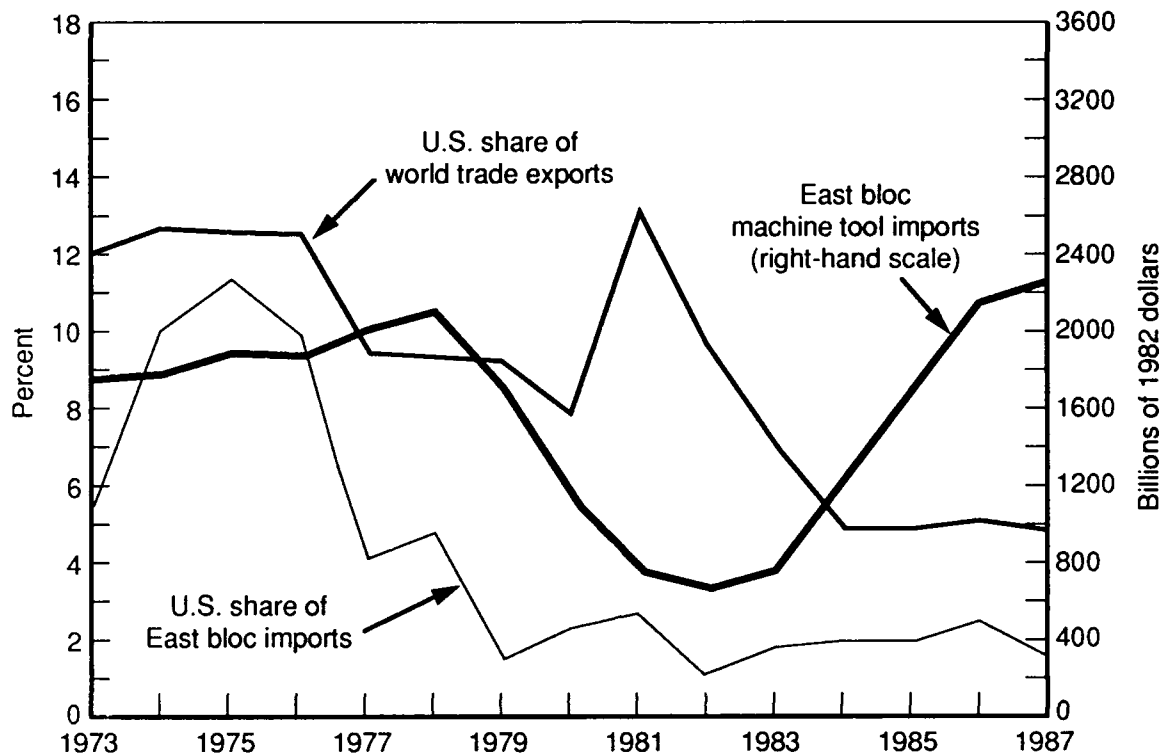


Fig. 8—East bloc machine tool trade—U.S. share, and share of world trade

## TRADE ADJUSTMENT ASSISTANCE

The Trade Act of 1974 (as amended in 1981) authorized trade adjustment assistance (TAA) upon a finding and certification by the Secretary of Labor that increases in imports were a "substantial cause" of unemployment of many employees of a firm.<sup>16</sup> Assistance comprises cash payments as a supplement to unemployment insurance, training, job search and relocation allowances, and employment services. In 1981 benefit levels were set equal to unemployment insurance levels (roughly 50 percent of the average weekly wage); the combined duration of TAA and unemployment insurance was not to exceed 52 weeks, except for workers receiving training. From 1976

<sup>16</sup>The term "substantial cause" has been interpreted as a cause that is important, and not less important than any other cause of decreased sales and employment. Aho and Bayard, 1984.



to 1980, the average annual benefits varied from \$1072 to \$4426, depending mainly on the average duration of unemployment.

In 1982, employment in the machine tool industry fell by 20,500 workers, 21 percent of the industry's total labor force. Petitions from 31 companies flowed into the Labor Department seeking assistance for 2211 employees.<sup>17</sup> Of these 31 petitions, seven were approved covering 953 employees, eight were denied, and two terminated without decision. At the end of the year, 14 cases were still pending. If the pending cases were decided in the same proportions as those that actually went to decision, an additional 300 employees would have received assistance, for a total of about 1250, or about 6 percent of the total fall in machine tool employment. If each beneficiary received the highest average annual amount of assistance of the preceding five years (\$4426), then the total value of benefits would have been around \$5.5 million; the actual level of benefits was most likely significantly less than \$5 million.

According to these figures, TAA to machine tool employees did not substantially affect the overall welfare of unemployed machine tool workers. Although it certainly would have been welcomed by individual beneficiaries, its value seems to be more as a political bargaining chip than as a trade adjustment program.<sup>18</sup>

## **NONTRADE RELATED MACHINE TOOL PROGRAMS**

### **Department of Defense**

The Department of Defense (DoD) has had a major influence on funding developments in manufacturing. Its Manufacturing Technology (ManTech) Program was responsible in the 1950s for the development and initial purchase of NC machine tools. It also promoted the development and dissemination of a standardized system of software for programming NC applications. From 1978 to 1982, annual ManTech funding levels increased from \$100 million to \$209 million, but then declined to \$71 million in 1990.<sup>19</sup> Total funding from 1978 to 1990 (unadjusted for inflation) was approximately \$1.9 billion.

---

<sup>17</sup>These figures come from NMTEA, *Petition*, 1983, pp. 117-118 and App. G.

<sup>18</sup>Aho and Bayard, 1984, p. 184, claim that the political gains of TAA "are enormous."

<sup>19</sup>U.S. International Trade Commission, 1983, p. 38; "Air Force's ManTech Flying Despite Cuts," *Metalworking News*, November 27, 1989, p. 1.

The U.S. Air Force has been the main actor in the ManTech Program, contributing more than 50 percent of the total funding. However, much of its effort has been aimed at areas other than the machine tool sector. In 1986, about 30 percent went to computer-integrated manufacturing, 20 percent to electronics integration and assembly, and 23 percent to improving the Air Force's own maintenance and repair activities.<sup>20</sup>

The effectiveness of the ManTech Program in promoting productivity has been questioned by many participants. An evaluation of the program noted that companies on the leading edge in process technology find themselves competing with government-sponsored programs supporting contractors that have chosen not to spend their own funds on production R&D. The question arises whether ManTech funds add incrementally to the field or substitute for R&D that industry would otherwise have paid for by itself.<sup>21</sup>

Industry surveys also criticize the length of time it takes to get an idea funded, with a minimum two-year lag cited as the norm. Furthermore, industry participants suggest that the really good ideas are privately funded.

Although the ManTech Program is the largest U.S. government initiative in manufacturing processes, only a small portion of the funds go to the machine tool sector, the efficiency of the process may be low, and the funded projects themselves may not be in high payoff areas. The major benefits noted by ManTech participants include a forum for the exchange of information free from antitrust constraints and management awareness of the importance of manufacturing investment and R&D.<sup>22</sup>

Other DoD programs include the Industrial Organization Incentives Program, which encourages defense contractors to invest in cost-saving technologies by sharing with contractors cost reductions brought about by innovations; the Integrated Computer Aided Manufacturing Program; the Air Force TechMod and Manufacturing Science programs; and the Navy's Precision Engineering and Industrial Modernization Incentives program. All of these DoD programs are intended to fund directly, or through various incentives to encourage the development of more efficient, flexible, higher capability, reliable, and less costly manufacturing processes.

A joint effort between private industry and the DoD created and financed the National Center for Manufacturing Sciences (NCMS). Organized in late 1987 as a cooperative venture of a hundred manufacturing companies (including machine tool

---

<sup>20</sup>Manufacturing Studies Board, 1986, Table B-1, p. 41.

<sup>21</sup>Ibid., pp. 31-32.

<sup>22</sup>Ibid., p. 32.

builders, users, and suppliers), the NCMS is promoting as its first major project an effort to define and initiate development of a "next-generation controller." The DoD has committed \$5 million per year for three years to the NCMS, and the Air Force is becoming involved in the controller project through its ManTech program.<sup>23</sup> Following great initial enthusiasm, considerable skepticism has developed in the industry over NCMS ability to achieve its goals.

The Defense Department operates two other major programs that affect the machine tool industry: the Defense Industrial Reserve and the Machine Tool Trigger Order Program. The industrial reserve is intended to cope with a mobilization of the type witnessed in the early stages of World War II and the Korean War. Many of the machine tools in the reserve were drawn largely from surplus machines produced for World War II and Korea. As a consequence, the 20,000 items in the reserve are obsolete equipment with an average age of more than 25 years. With such obsolescence occurring constantly, the rationale for maintaining such a stock has been seriously questioned.

Other mobilization investments include the system of government-owned plants, again a relic of World War II. Many of these plants no longer satisfy defense production requirements, and the government has been gradually eliminating them. Plant equipment packages are still another attempt to stock sets of necessary equipment to produce specific armaments and munitions. This program, too, is deficient in that the sets are out of date and incomplete, with an average age of more than 25 years.<sup>24</sup>

The Trigger Order Program allows the DoD to negotiate in advance the machine tool types and terms of sale that participating manufacturers would be expected to supply in the event of a declared national emergency. Trigger Orders, however, do not provide for the purchase or induce the production or improvements of machine tools. Their main purpose is to save time negotiating contracts during a national emergency.<sup>25</sup>

These mobilization programs appear to have little effect on current machine tool activities and behavior. The other DoD programs that fund and encourage R&D do have lasting effects on machine tool and manufacturing technologies. In terms of adaptation to global competition, the "next-generation controller" project has the potential to greatly advance machine tool productivity throughout manufacturing, which in many

---

<sup>23</sup>"NCMS Joins Air Force on New Controller," *Metalworking News*, September 5, 1988, p. 1.

<sup>24</sup>NMTBA Petition, 1962, p. 180.

<sup>25</sup>*Ibid.*, pp. 184-185.

applications is now limited by the speed, flexibility, and adaptability of the control systems.<sup>26</sup>

### **National Bureau of Standards (NBS)**

Since 1968, the NBS has operated a Center for Manufacturing under its National Engineering Laboratory. Much of their effort has been devoted to developing standardized interfaces permitting, for example, better communications among CAD/CAM systems. Other research on automation, control technology, and robotics evolved into the Automated Manufacturing Research Facility, a flexible manufacturing system intended to investigate precision machining and robotics and available to universities and private companies for nonproprietary research. Although this prototype computer-integrated manufacturing system was designed to support research on standards, it has been used by several companies for pioneering complex automated manufacturing systems. Cincinnati Milacron, for example, developed its hierarchical control concepts for its T-3 robot system on the NBS facility.<sup>27</sup>

From 1982 to 1984, NBS appropriated about \$5.5 million annually on its manufacturing engineering program. Because of the unique contributions of much of its research work, the NBS funds are augmented by funds from other government agencies, including the three military services and NASA. In 1984, these additional funds added \$5.3 million to the NBS appropriation.<sup>28</sup> This cooperation among NBS, the Navy, and equipment manufacturers led to an integrated, computerized work station at the U.S. Naval Shipyard at Mare Island, California. This operation represents the first attempt to transfer an entire system from NBS labs to a manufacturing environment.<sup>29</sup>

### **National Science Foundation (NSF)**

The primary manufacturing-related program of NSF is the Production Research Program. Its goals are to support research that may lead to substantially higher productivity, and to insure a sufficient number of manufacturing engineers for universities and industry. The annual funding for the Production Research Program in

---

<sup>26</sup>"Companies Team Up to Develop Better Tools," *The Wall Street Journal*, December 1, 1987.

<sup>27</sup>"Tomorrow's Factories Today," *Manufacturing Technology*, September 1988, p. 50.

<sup>28</sup>USITC, 1983, p. 43.

<sup>29</sup>"Tomorrow's Factories Today," p. 91.

the mid-1980s was about \$4 million–\$5 million, which was allocated mainly for university research.<sup>30</sup>

### **Government Laboratories**

Many government laboratories, particularly in the Department of Energy (DOE), conduct research for their own agencies' use related to machine tools and manufacturing. Several laws in the 1980s attempted to make the results of research performed by government agencies more available to the public. Technology transfer programs were vigorously adopted by the Lawrence Livermore National Laboratory and other DOE laboratories. For example, Livermore has been instrumental in developing computing methods used in finite element analysis, an engineering method finding increased use in machine tool design. Although the total value of such research is unknown, it is likely at least to equal the sums spent by NBS and NSF.

### **SUMMARY**

The machine tool industry has benefited from policies intended to ameliorate the declines in business related to imports, mainly VRAs and TAA. In other government programs, the DoD's ManTech is the most important and the largest of any government activity targeted explicitly at manufacturing and machine tools. The other military services also make sizable investments in manufacturing technology. The National Center for Manufacturing Sciences has declared that its controller project could cost up to \$100 million over a three- to five-year period, although only initial, lower funding levels have been authorized. Although the U.S. government contributes considerable amounts of resources to machine tools and the manufacturing sector, and is responsible for additional funds flowing to the industry through its trade policies, only a small proportion of these resources result from machine tools being defined as a declining or structurally adjusting industry. Many of the government's programs grow out of its own perceived needs as a buyer of the products ultimately produced by the products of the machine tool industry. Its other programs, those of the NSF and NBS, are intended to enhance the general productivity of the U.S. economy by funding programs with a potential for high social returns that few firms would wish to do on their own (for

---

<sup>30</sup>USITC, 1983, pp. 40–41 and App. G.

example, the establishment of industrial standards). However, some of the most important policies affecting the machine tool industry are not directly aimed at this target at all, but act through general political and economic forces.

#### **IV. NONSPECIFIC POLICIES AFFECTING THE MACHINE TOOL INDUSTRY**

##### **MACROECONOMIC POLICIES**

A rapid scan of the evidence on the cyclical nature of the machine tool business provides ample demonstration that government policies influencing macroeconomic behavior have a multiplier effect on machine tools. Similarly, the sharp decline in machine tool exports and the surge of imports in the 1980s followed from the same macroeconomic causes that created unprecedented trade deficits for the rest of the economy. The origins of most of the important government policies that affect machine tools have almost nothing to do with machine tools, or with secularly declining industries, or with the effects of trade on such industries, but with more general economic policies, political judgments, and world developments.

When we asked machine tool company officials to identify their most pressing problems, the typical responses were: "the high value of the dollar," "a weak U.S. economy," or "high interest rates." When pressed to suggest policies that would be most helpful, their common reply was to reduce the overwhelming problems facing them, rather than to initiate specific programs, such as trade adjustment assistance.

The chief economist of a nonprofit organization specializing in rescuing foundering machine tool companies placed government policies in three layers. At the top were those affecting the macroeconomic situation, such as unemployment levels and foreign trade conditions. These policies established the business climate in which the companies found themselves. At the middle level were policies specifically directed toward the industry; VRAs and TAA were examples. These were said to be helpful, but ameliorative at best. At the lowest level were the programs that a company, community, union, or management group could access directly. These programs usually involved financing: for inventory investment, employee or management buyout of a plant or company, equipment purchase to increase efficiency or to meet a potential order, or R&D to develop new models.

State governments in particular have been moving into the financial area with a variety of industrial financial boards, agencies, and public corporations. These entities were designed to fill a perceived gap in industrial financing. Massachusetts, for example, established an Economic Stabilization Trust that could make loans to troubled companies

unable to secure financing from conventional sources. These state services are based on the explicit notion of a failure of financial markets to make profitable loans.

## **PROBLEMS IN FINANCE AND CAPITAL**

In conversations, interviews, and reviews of the industry trade press and analytical studies, comments about insufficient financing appeared as a constant undercurrent. Adjustment to changing circumstances inevitably requires capital. High financing costs or barriers to financial sources will impede the ability of firms to adapt to competitive challenges. Understanding financial problems and their sources, therefore, is important in the responsiveness of the U.S. machine tool industry to shifting demands, new technology, and global markets. Although much of this is still conjectural, sufficient casual evidence exists to indicate the possibility of a major problem.

### **Examples of Financing Problems**

To demonstrate the variety of issues raised by perceptions of inadequate financing, the following statements have been drawn from a range of sources. Although these statements do not always explicitly deal with financial issues, problems of financial adequacy will be seen to lie behind them.

When the demand for machine tools revives, it may be supplied in major part from enormous inventories of Japanese products in this country. . . . Unable to produce for inventory, U.S. manufacturers will lose increasingly more sales.<sup>1</sup> *Problem: Compared with Japanese firms, U.S. firms are less able to finance inventories.*

The industry's cycles have: (1) made a high debt-equity ratio imprudent, if not impossible, in light of the attitudes of lending institutions toward debt-service coverage during downturns in the business cycle; . . . and (3) restricted that industry's ability to expand its production rapidly in response to increases.<sup>2</sup> *Problem: Cyclicalities reduces financial backing.*

The risks of investing in the machine tool business are reflected by the uncertainty of the industry's earning performance over the years. . . . Fluctuations are greater than those experienced by manufacturing industries generally. . . . Redeployment of capital within conglomerates may be

---

<sup>1</sup>NMTBA, *Petition*, 1983, pp. 12-13. Various estimates placed the value of the Japanese stock of finished machines in the United States at \$500 million, requiring at least \$50 million per year in carrying charges (interest, warehousing costs, depreciation).

<sup>2</sup>*Ibid.*, p. 35.



prudent from the standpoint of the companies involved.<sup>3</sup> *Problem: Fluctuating profits reduce financial attractiveness.*

The Japanese may have manufactured machine tools for which there was no current demand simply to achieve production experience and the cost savings that it produces.<sup>4</sup> *Problem: Japanese firms have sufficient capital to invest in cost-reducing production.*

Historically, it has been difficult for the U.S. machine tool industry to generate capital. The cyclical nature of the industry . . . has made it difficult for machine tool producers to attract external equity or debt financing. . . . Since the majority of U.S. companies are small and privately held, few financial institutions are willing to assume the risk. Debt-to-equity ratios in the U.S. industry are typically below 50 percent. . . . The ability to generate capital in foreign industries does not appear to be so burdensome. Japanese debt-to-equity ratios have been reported to range from 150 to 560 percent, . . . and the risks associated with capital expansion are, in effect, assumed by the lending agency.<sup>5</sup> *Problem: Small, cyclical, family-held firms in the United States cannot attract capital; this is not the case in Japan.*

Some 80 percent of manufacturing in the U.S. is done by small shops of less than a few hundred people. They are really undercapitalized and not in any position to do any meaningful research.<sup>6</sup> *Problem: Small firms cannot attract capital to perform R&D.*

The severe swings in volume reduce the investment attractiveness of the industry and lead to undercapitalization. This, in turn, severely impedes the upgrading of facilities and introduction of new technology. . . . Small family-owned U.S. firms are poorly equipped to pursue international sales. Furthermore, Eximbank loan criteria focus on transactions that are much larger than typical machine tool sales.<sup>7</sup> *Problem: Cyclical, small, family-owned firms are financially unattractive and cannot invest in equipment technology or foreign sales.*

There will be more concentration in the industry because the cost of developing higher technology will be beyond the mom-and-pop operations—and the medium-size companies too.<sup>8</sup> *Problem: Industry concentration (and monopolization) will increase because small firms cannot attract capital.*

---

<sup>3</sup>Ibid., p. 128.

<sup>4</sup>Ibid., p. 154.

<sup>5</sup>USITC, 1983, p. 99.

<sup>6</sup>Statement by James Koontz, Chairman of the National Center for Manufacturing Sciences, quoted in "Companies Team Up to Develop Better Tools," *The Wall Street Journal*, December 1, 1987.

<sup>7</sup>Hannay and Steele, 1986, pp. 17–18.

<sup>8</sup>Statement by Paine Webber's machine tool industry financial expert Eli Lustgarten, in "Will Machine Tools Survive This One," *New England Business*, October 17, 1983, p. 15.

High tech machines that Americans are capable of building have indeed been installed to a higher degree in Japan. Why? Japanese businesses can write off new investments in a short period of time with low-cost loans. Here, Gray said, we have the "the knowledge of the technique, but we don't have the wherewithal to buy it and put it in our plants."<sup>9</sup> *Problem: U.S. tax rules impede investment.*

Once in the U.S., Japanese companies expanded their presence, offering deep discounts below list prices and favorable financing terms.<sup>10</sup> *Problem: Japanese firms can afford investments in low prices that will reduce profits in the short term, but gain market share at lower costs in the long term.*

American industry is technology rich, but implementation poor. . . . One of the reasons is our costing strategy. Many companies have justification policies that require a capital investment to pay back in two years or less. . . . Justification windows should be at least five to seven years. Our foreign competition uses that time frame.<sup>11</sup> *Problem: U.S. firms require a rate of return that is very high.*

It took little to convince LeBlond of the merger's benefits, since he had been searching for some way to give family shareholders some stock liquidity. . . . In return, Japan's Makino Milling Machine Company would spend millions updating LeBlond's headquarters in Cincinnati, helping move the company into the latest technology while continuing to strengthen its lathe business.<sup>12</sup> *Problem: A family-owned firm could not raise capital.*

In 1979 cash-rich Warner & Swasey faced an unfriendly takeover bid from AMCA International. But a white knight came to the rescue: Bendix Corporation was willing to pay \$301 million, nearly twice book value. . . . And the business continued to boom. "We took out \$100 million to \$150 million of positive cash flow in the first 18 to 24 months after the acquisition," recalls William M. Agee, then Bendix's chairman. Smith says that this hurt Warner & Swasey's ability to respond to the market.<sup>13</sup> *Problem: A U.S. conglomerate had a short-time horizon, implying a high cost of capital.*

U.S. firms have real difficulty in pricing competitively in overseas markets. This fact is a result of . . . the difficulty that the industry has in raising capital at a reasonable cost, and a host of other factors.<sup>14</sup> *Problem: High capital costs impede competitiveness.*

---

<sup>9</sup>Statement by James Gray, NMTBA President, cited *ibid.*, p. 17.

<sup>10</sup>Statement by W. Paul Cooper, chairman of Acme-Cleveland Corp; cited *ibid.*, p. 18.

<sup>11</sup>"Machine Tool Technology: The March Presses On," *Modern Machine Shop*, February 1988, p. 93.

<sup>12</sup>"LeBlond Gets All-American Management," *Cincinnati Inquirer*, August 3, 1987.

<sup>13</sup>"Bendix: A Buy that Really Was Too Good to be True," *Business Week*, June 3, 1985, p. 93.

<sup>14</sup>Testimony of James A. Gray, NMTBA President; NMTBA, *Petition*, 1983, App. K, p. 4.

When the Yamazaki Machinery Company in Japan installed an \$18 million flexible manufacturing system, the results were truly startling: a reduction in machines from 68 to 18, in employees from 215 to 12, in production floor space from 103,000 square feet to 30,000 and in average processing time from 35 days to 1.5. However, the project's return [measured according to typical U.S. methods] was less than 10 percent per year. Since many U.S. companies use hurdle rates of 15 percent or higher and payback periods of five years or less, they would find it hard to justify this investment in new technology—despite its enormous savings in number of employees, floor space, inventory, and throughput times.<sup>15</sup> *Problem: U.S. firms require high rates of return and may use inappropriate criteria.*

When 67 Cleveland firms were asked whether they would be able to obtain finance for capital improvements, 51 percent said they they would have a problem. . . . The highest percentage expecting problems represented the smallest firms. The difference among size classes was quite substantial: only 45 percent of those with more than 50 employees expected problems compared with 75 percent of small firms. Only two identified *availability* as a problem. The bulk identified the problem as excessively high payments.<sup>16</sup> *Problem: The high cost of capital reduces capital improvements, especially for small firms.*

The purpose of this litany is to demonstrate the persistence and the diversity of effects that the capital and finance issue raises in the eyes of industry representatives and analysts. At this point, we cannot say whether these perceptions are accurate. These views could, on closer examination, turn out to be rationalizations for poor performance or well-rehearsed myths passed from one speaker to another.

### **Hypotheses on Sources of Possible Financial Problems**

Two reasons could explain the putative failure of financial markets to service the machine tool industry. The first reason is insufficient savings in the United States to channel into investments.<sup>17</sup> According to this argument, the cost of funds is "too high" relative to some unstated standard: a customary previous cost, the cost in other countries, the cost that would justify a desirable investment (desirable on other grounds than profitable rate of return), the cost that would prevail if some policy were changed. The second reason is that biases or imperfections exist in the capital market that affect some class of firms or investments and direct funds away from profitable investments; such biases could arise from regulatory or legal constraints on market structure or lending

---

<sup>15</sup>Kaplan, 1986, p. 87.

<sup>16</sup>Reuter, 1983, pp. 24–26.

<sup>17</sup>Of course, this reason would apply to all industry, not just machine tools.

criteria, or from other failures in market behavior. These market failures or biases are implied to operate primarily against small firms.

According to the first hypothesis, aggregate savings rates are the culprit behind the presumed financial inadequacies. A great deal of evidence supports this view. For several decades, U.S. savings as a proportion of national income has fallen considerably below the levels of most other industrial countries, particularly those that are the most active competitors to U.S. industry. In the 1980s, the low rate of national savings was exacerbated by large and persistent government deficits and by household savings falling to unprecedentedly low levels. However, the 1980s also witnessed the rapid growth of international movements of capital, which tend to balance out the supply and demand for capital on a worldwide scale. Notwithstanding the massive transfers of capital across national boundaries, though, this market is still in the development stage and borders may still matter, especially for small firms. Although national savings insufficiency may be less of a problem in the future because of the internationalization of capital markets, past savings insufficiency may be a partial explanation for the perceptions of financial problems in the U.S. machine tool industry.

Despite the absence here of independent confirmation of capital market failures, one body of evidence is broadly consistent with the hypothesis that smaller companies in the United States suffer in comparison with large companies in financial markets. This evidence consists of the trend toward industrial concentration that has proceeded in the United States since the 1950s despite any compelling demonstration of scale economies in production. Mergers, takeovers, acquisitions, and buyouts appear to be driven largely by financial considerations, implying that a merged company is more profitable than unmerged firms. The structure of U.S. financial markets may be responsible for such a bias, especially when compared with the Japanese financial system.

### **The Structure of Financial Markets**

The U.S. financial system has been described as one based on capital markets that allocate resources by competitively established prices. This type of system places banks, firms, and governments in distinct and separate spheres, operating through arm's length

relationships in which financial institutions will not routinely have influence inside business firms.<sup>18</sup>

A different kind of credit-based system has operated in Japan, although the Japanese financial system is now moving toward the U.S. model. In an abstracted model of such a system, market interrelationships are dominated by government-administered prices. Capital markets are not easily accessible to private borrowers. Firms must turn to lending institutions for the funds they need. The borderlines between government bureaucracy, finance, and borrowers blur, and banks operate in close collaboration with their borrowers. In this kind of system, bankers and firms form tight relationships with a great amount of detailed information passed to the banker for review and analysis. Debt-equity ratios that may appear forbidding to an arm's length lender could be more acceptable to a lender who participates almost as a company insider.

With the deregulation of the Japanese financial sector, however, we find a major trend away from bank lending and toward market-oriented bond and equity financing. Although the regulated system of the past may have had many advantages, the removal of constraints has permitted firms to alter their previous behavior in a way that is apparently preferred to the old approach, and closer to the American approach to company finance.

The United States, then, has a highly developed capital market but one that many observers believe is designed to satisfy the needs of large and impersonal borrowers, about which considerable amounts of information are available to market participants. The country also has a solid venture-capital market designed to support start-up firms. But for a company of 50 employees seeking \$20 million in financing to buy new production equipment or to invest in product development, the U.S. financial market may be inadequate.<sup>19</sup>

In Japan, the government and Diet structured capital markets to support small business through the creation of specialized banks, credit associations, and government

---

<sup>18</sup>The arguments in these paragraphs flow from Zysman, 1983.

<sup>19</sup>A casual survey of knowledgeable individuals in the financial industry is strongly consistent with this statement, indicating that the small business borrower suffers from grossly higher capital costs than large borrowers, mainly because of the structure of the financial market. This point needs additional investigation.

lending agencies.<sup>20</sup> Because small business became the core of the postwar Liberal Democratic Party,

successive legislative efforts created a vast array of private and government institutions committed to making loans for small-scale enterprises. In effect, the Japanese created an industrial equivalent of the American savings and loan system for the U.S. housing market. . . . This redirection of capital markets toward small firms nurtured the independent expansion of small companies.<sup>21</sup>

For example, mutual (*sogo*) banks and credit associations were tightly restricted to specific geographical areas. City banks were blocked from opening branches in many of these areas, leaving the small regional banks that served small local business in a favored competitive situation. The government also established several financial institutions to supply funds to the mutual banks and credit associations, and to small business directly. Thus, the Small and Medium Enterprise Finance Corporation was limited to lending to firms with fewer than three hundred employees. The Central Commercial and Industrial Bank was made the coordinating institution for credit unions and made 70 percent of its loans to small enterprises. The central government put up half its capital, and localities and other government institutions put up the rest.<sup>22</sup> However, as Japan ends a decade of deregulation and the internationalization of capital flows, these past advantages of small firms may be disappearing.

### Summary Issues

There are still many tantalizing analytical questions with an important bearing on policy. Is there a market failure in the United States in the capital market's behavior toward small firms? If so, does it arise from law or other regulatory activity? Does Japanese political attention to small business correct deficiencies arising from market failure or is it a pure gift to important political backers? Does U.S. small business face inadequate financing, or does it only appear so in comparison with Japanese practice? What kind of government policies may be responsible for financial shortfalls, what may be done about them, and how would they affect the ability of U.S. machine tool producers to adapt to the contemporary situation? These questions would benefit from future research.

---

<sup>20</sup>This argument follows Friedman, 1988, pp. 161–175.

<sup>21</sup>Ibid., p. 167.

<sup>22</sup>Ibid., p. 170.

## **V. FURTHER SPECULATIONS ON THE DECLINE OF THE U.S. MACHINE TOOL INDUSTRY**

### **THE CLEAR AND THE FUZZY REASONS FOR DECLINE**

The decline of the American machine tool industry in the 1980s was undoubtedly the result of many forces well beyond the industry's control: a secular fall in the domestic demand for machine tools, an overvalued dollar, a sharp recession, and problems in capital availability. However, it must also be acknowledged that the worldwide demand for machine tools was growing; that hundreds of small companies in the United States (biotechnology firms, for example) were able to raise billions of dollars in new capital in that same, tight, high-interest decade; and that the machine tool industry had faced cyclical ups and downs for its entire 125 year history. Something else was clearly at work, and a good deal of that "something else" was Japanese.

One part of the U.S. machine tool industry's problem arose from the forces of the classic product life cycle. As products mature, they can often be produced more economically in countries with lower labor costs, even though the industrial capabilities of those countries are not equal to the capabilities of the more advanced economies. This pattern was seen in machine tools as South Korea, Taiwan, Spain, and Japan reproduced virtual copies of 1930s U.S. machine tool models and sold them cheaply around the world, competing at the lower technological end of the market.

### **THE JAPANESE CHALLENGE**

Product life cycle was only part of the story, as Japanese producers in the 1970s entered the market with cost-effective NC and CNC machines; their earliest and most successful entry in this market was the CNC lathe. The key factor in the Japanese success was the design of lower performance, smaller, simpler, less expensive models. The target market for these designs was primarily small and medium-sized machine shops and manufacturers, which demanded a somewhat different product from the larger firms. One measure of this difference is in the weight of the machine tool: In the 1970s, the average weight of Japanese CNC lathes was about 5 tons, whereas CNC lathes produced in West Germany were over 13 tons.<sup>1</sup>

---

<sup>1</sup>Jacobson, 1986, Table 3.7, p. 48.

The success of the Japanese companies in opening up and developing this market sector domestically, and then using this base to penetrate international markets, mirrors a broader pattern of Japanese behavior. The major force working on the Japanese machine tool companies was the fiercely competitive domestic market, which was characterized by thousands of medium and small enterprises that were simultaneously the potential customer base and the suppliers of parts and components of machine tool producers and other manufacturers. The machine tool builders concentrated on the requirements of these smaller firms, which were motivated to adopt the most productive equipment. To reduce costs, the machine tool producers emphasized standardized machines. The development of cheap, standardized control units by the Japanese electronics firms responded to the demands of the machine tool producers.<sup>2</sup>

The machine tool firms competed sharply among themselves because of rapid overexpansion of capacity and the entry of new companies into existing product lines. In 1975, for example, 25 companies fought for the CNC lathe market; this number expanded to 37 companies by 1983.

With the possibility of large unit sales to the small machine shops in mind, many of the machine tool firms invested in seemingly excessive plant capacity and priced their products with a view toward eventually achieving scale economies that would justify the low prices. Indeed, the five largest Japanese CNC lathe producers incurred losses from 1975 to 1978.<sup>3</sup> However, the production of these same five firms expanded from 275 units in 1978 and to almost 2200 by 1980, at which time the firms became quite profitable.<sup>4</sup>

This base of product design, production capacity, and reduced costs from both low-cost designs and high quantity of output placed the Japanese industry in position to compete vigorously for the foreign market. In 1975, the Japanese share (by value) of the non-Japanese world market for CNC lathes was only 5.6 percent. Within five years, these companies had captured more than a third of the world market (35.7 percent). Penetration of the American market was even greater, reaching two-thirds of U.S. consumption by 1986.<sup>5</sup>

---

<sup>2</sup>Ibid., p. 65.

<sup>3</sup>Ibid., Table 3.10, p. 51.

<sup>4</sup>Ibid., Table 3.9, p. 50.

<sup>5</sup>This figure refers to vertical and horizontal NC turning machines. *NMTBA Statistical Report*, No. 57-89, May 3, 1989.



The reasons offered above for the success of the Japanese machine tool producers rest largely on the competitive nature of the producer and user industries, on the product designs, and on the risky expansion of capacity combined with pricing for quantity production and sales. Some other reasons have been suggested, but they often do not hold up to close inspection. The most commonly asserted include Japanese government guidance and coordination, industry cartels, and government subsidies.

The Japanese Ministry of International Trade and Industry did indeed have policies for the machine tool industry; in fact, it had such policies since the 1930s. These policies emphasized the consolidation of firms into larger units, the allocation of machine types to established firms to gain scale economies, and the collaboration of firms within cartel-like associations to control capacity expansion. MITI also promulgated plans for exports, imports, and entry into NC markets. According to evidence on actual behavior gathered and analyzed by David Friedman, none of MITI's machinery policies were successful.

In the period of planning and financial support, output objectives had no effect on industry performance, while government loans did not generate economic expansion. The cartelization phase did not reduce firm entry or market volatility, nor did it rationalize production. . . . NC development and export successes were not the result of government or private efforts to coordinate production and marketing abroad. Rather, they were generated by a domestic demand for new tools which producers in other countries apparently ignored. . . . In no single instance did MITI's policies lead to anticipated market outcomes. *This failure helped promote flexible manufacturing in Japan.*<sup>6</sup>

Government subsidies were mainly granted through loans from the Japan Development Bank (JDB), which accounted for 90 percent of all government support to the machinery industry. In the decade 1956-1965—the years of most active government support—JDB loans averaged 11.5 percent of total capital investment in the machine tool industry.<sup>7</sup> In subsequent years, JDB loans were close to zero until 1983 when they rose to about 3-5 percent of industry investment. Interest rate savings on these loans averaged 0.8 percentage points under the prime rate.

Another alleged source of government subsidies was the "hidden" proceeds from gambling on bicycle and motorcycle racing. Estimates of the annual subsidies and grants

---

<sup>6</sup>Friedman, 1988, p. 72, emphasis added.

<sup>7</sup>Ibid., p. 87.

from the source range from about \$340,000<sup>8</sup> (mainly for the support of trade shows), to \$112 million<sup>9</sup> (for the whole "machinery" industry), to \$985 million.<sup>10</sup> Wolf's figure of \$985 million would have amounted to about one-third of total industry sales in the early 1980s, a sum that would have been difficult to conceal. A smaller figure of \$104 million, also cited by Wolf, is consistent with those of the other sources for the much broader machinery sector. Saxonhouse's figure of \$340,000 is the machine tool share of the approximately \$100 million going to the machinery sector. Certainly, a subsidy of close to a billion dollars would go a long way toward explaining the success of the Japanese machine tool industry. The better supported sum of \$0.34 million, though, could not be a major contributor to industry performance.

### AMERICAN RESPONSIVENESS

A central question regarding sources of Japanese success concerns the reasons for the American industry's failure to respond to the market opportunities of the small machine shop and to meet the Japanese challenge once that market was revealed. As in the Japanese case, numerous explanations have been offered, but these are usually little more than assertions and allegations with little research backing. Possible constraints could arise from the structure of capital markets and the cost of capital. March discusses in detail the litany of allegations explaining the collapse of the American industry, including: fragmentation and parochialism of small, family-owned firms and the insidious incentives on publicly held firms; industry cyclicalities; lagging product innovation; weak user pull; competitive complacency among American manufacturers; low user sophistication; lagging producer investment; the effects of large user domination of NC developments; the failure of U.S. schools of engineering and management; short-term thinking and the structure of capital markets; and "the failure of American government policy leaders to develop a vision of, and political support for, the requirements for the long-term commercial viability of the United States, and the critical role of machine tools to that viability."<sup>11</sup>

---

<sup>8</sup>Saxonhouse, 1986, p. 226.

<sup>9</sup>Okimoto, 1986, p. 65.

<sup>10</sup>Wolf, 1983, p. 76.

<sup>11</sup>March, 1989, pp. 8-31.

These assertions, based on wide-ranging interviews, should be considered as hypotheses to be tested by the usual methods of empirical research. I suggest that some genuine puzzles confound our understanding of competitive markets, and that concepts of industry dynamism play an important but poorly understood role. The American machine tool industry ought to be competitive, according to the usual notions of numbers of actual or potential entrants. More than 40 firms produce milling machines; 37 companies produce products in machining centers; and 56 companies produce products in the turning machine business.<sup>12</sup> Each of these broad categories, however, are divided into specialized niches, the members of which may not compete against members of other niches; for example, the 56 turning machine companies are distributed in 12 separate categories. However, each of the categories has at least ten members, and the barriers impeding a company in one category from entering another are not large: Neither the required investment nor the additional learning for efficient production, design, and marketing are immense, as many of the major components of a machine tool are quite similar across different types.

The argument that small firms are not good at innovation is contradicted by almost every empirical study on the sources of innovation. For example, a study of 8000 product and process innovations across 500 industries (standard industrial classification, 4-digit industry classifications) found more than half of the innovations coming from firms with fewer than 500 employees. These smaller firms had about 50 percent more innovations per industry employee than larger firms.<sup>13</sup> Moreover, the smaller firms' innovations were as likely to be "significant" as those of the larger firms. However, the innovation rate per industry employee for industries with declining employment (which characterizes the machine tool industry) was only half as great as for those with growing employment, for both large and small companies.

A survey of nine studies sponsored by the Small Business Administration confirmed the generality of these results.<sup>14</sup> Some of the other studies also show that innovating smaller firms (in comparison with larger firms) conduct more basic and more applied research than development, bring an innovation to market more quickly, conduct

---

<sup>12</sup>These figures are the member companies of the NMTBA that are listed under the designated categories, *NMTBA Directory*, 1989.

<sup>13</sup>Gordon and Edwards, 1984.

<sup>14</sup>Schrier, 1989.

more R&D per sales, and are as likely to export.<sup>15</sup> The export tendencies of small firms were demonstrated by the statistics that 41 percent of firms with 50-99 employees are exporters, 48 percent of firms with 100-499 employees, and only 27 percent for those over 500.<sup>16</sup> In the metalworking machinery sector, two-thirds of the companies with fewer than 100 employees are in the export markets.

What we are left with is a genuine puzzle. Why did not some American company introduce new ideas for products and production processes before the Japanese companies, and why has it been so difficult to respond to the competitive challenge? The answers to these puzzles will not be found in the recitation of opinions and the retelling of widely shared beliefs, but in real research.

The 1980s witnessed an unprecedented concatenation of circumstances affecting the U.S. machine tool industry. Recession; an overvalued dollar; the rise of the Japanese industry; the shift in technology toward electronics, software, and controls; the demands for flexibility and faster delivery; the vertical disintegration of production; the integration of single machines into larger systems; and the globalization of markets placed an unusually grave and complex set of problems before the machine tool industry, much of which was family owned and managed, dating back to the U.S. civil war or earlier. Over the past century, many of these same companies met severe challenges posed by events as compelling as those faced today, although it is no exaggeration to say that the number and variety of challenges today meets, if not exceeds, anything seen in the past.

As we move into the 1990s, we will have a century and a half of growth, 30 years of secular decline, and a decade of plummeting sales: in short, 150 years experience of meeting challenges. Although some of the recent problems have declined in their acuteness (the United States has experienced almost a decade of economic expansion and several years of a more reasonably valued foreign exchange rate), the other issues remain no less pressing. The next few years will reveal the adaptations of the U.S. machine tool industry to shifting global forces.

---

<sup>15</sup>These additional findings are not found consistently across all the surveyed studies; sometimes the differences were statistically significant and other times not, but in no case was the opposite result found in the data.

<sup>16</sup>Birch, 1988, p. 42.

## BIBLIOGRAPHY

- Aho, C. Michael, and Thomas O. Bayard, "Costs and Benefits of Trade Adjustment Assistance," in Baldwin and Krueger, 1984.
- Alexander, Arthur J., *Approaches to Innovation in the United States and Japan*, The RAND Corporation, R-3924-CUSJR, 1990.
- Bailey, Martin Neil, and Alok K. Chakrabarti, *Innovation and the Productivity Crisis*, Brookings Institution, Washington, D.C., 1988.
- Baldwin, Robert, and Anne Krueger (eds.), *The Structure and Evolution of Recent U.S. Trade Policy*, University of Chicago Press, 1984.
- Birch, David L., "Trading Places," *Inc.*, April 1988.
- Daly, Ann, and Daniel Jones, "The Machine Tool Industry in Britain, Germany, and the United States," *National Institute Economic Review*, May 1980.
- Economic Handbook of the Machine Tool Industry*, NMTBA, The Association for Manufacturing Technology, various issues.
- Friedman, David, *The Misunderstood Miracle: Industrial Development and Political Change in Japan*, Cornell University Press, Ithaca, N.Y., 1988.
- Gordon, Theodore J., and Keith L. Edwards, *Characterization of Innovations Introduced on the U.S. Market in 1982*, The Futures Group, Glastonbury, Conn., March 1984.
- Hannay, N. B., and Lowell W. Steele, "Technology and Trade: A Study of U.S. Competitiveness in Seven Industries," *Research Management*, January-February 1986.
- Jacobson, Steffan, "Growth and Market Structure in the International CNC Lathe Industry," *Electronics and Industrial Policy*, Allen & Unwin, London, 1986.
- Jones, Sam L., "Japanese Tool Builders Little Affected by VRAs," *Metaworking News*, June 19, 1989.
- Kaplan, Robert S., "Must CIM be Justified by Faith Alone?" *Harvard Business Review*, March-April 1986.
- Manufacturing Studies Board, *The Role of the Department of Defense in Supporting Manufacturing Technology Development*, National Academy Press, Washington, D.C., 1986.
- March, Artemis, "The U.S. Machine Tool Industry and its Foreign Competitors," *MIT Commission on Industrial Activity*, Vol. 2, MIT Press, Cambridge, Mass., 1989.
- Milgrom, Paul, and John Roberts, "The Economics of Modern Manufacturing: Technology, Strategy, and Organization," *The American Economic Review*, June 1990.
- Moskal, Brian, "Twin Towers of Tools: Acquisitions Create a New Player," *Industry Week*, September 19, 1988.

- NMTBA, *Petition Under the National Security Clause, Section 232 of the Trade Expansion Act of 1962 for Adjustment of Imports of Machine Tools*, 1983.
- Okimoto, Daniel, "Regime Characteristics of Japanese Industrial Policy," In Patrick, 1986.
- Patrick, Hugh (ed.), *Japan's High Technology Industries*, University Press, Seattle, 1986.
- Pratten, C. F., "Economies of Scale for Machine Tool Production," *The Journal of Industrial Economics*, Vol. 19, 1970-1971.
- Rendeiro, Joao O., "How the Japanese Came to Dominate the Machine Tool Business," *Long Range Planning*, Vol. 18, No. 3, 1985.
- Reuter, Peter, *Cleveland Metal Stamping: A Case Study of an Industry in Transition*, The RAND Corporation, N-1977-CF, April 1983.
- Rousslang, Donald J., and Walter A. Pollard, *The Economic Effects of Significant U.S. Import Restraints, Phase 1: Manufacturing*, U.S. International Trade Commission, USITC 2222, October 1989.
- Saxonhouse, Gary R., "National Security Claims of the Trade Expansion Act," in Saxonhouse and Yamamura, 1986.
- Saxonhouse, Gary R., and Kozo Yamamura (eds.), *Law and Trade Issues of the Japanese Economy*, University of Washington Press, Seattle, 1986.
- Schrier, William, *Innovation, Small Business, and Government*, Small Business Administration, Washington, D.C., 1989.
- Schumpeter, Joseph A., *Capitalism, Socialism, and Democracy*, Harper, New York, 3d Ed., 1950.
- U.S. Department of Commerce, International Trade Administration, *Fact Sheet, Machine Tools*, Washington D.C., December 16, 1986.
- U.S. International Trade Commission, *Competitive Assessment of the U.S. Metalworking Machine Tool Industry*, USITC 1428, September 1983.
- Winter, Ralph, "Foreign Stake in Capital Goods Grows in U.S.," *Asian Wall Street Journal*, January 23, 1990.
- Wolf, Marvin J., *The Japanese Conspiracy*, Empire Books, New York, 1983.
- Zysman, John, *Governments, Markets, and Growth: Financial Systems and the Politics of International Change*, Cornell University Press, Ithaca, N.Y., 1983.